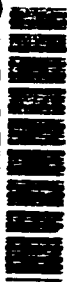


AD-A286 895



91311R01
VERSION 3.1
VOLUME II
2ND COPY



COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-0095

**AIR QUALITY DATA ASSESSMENT REPORT
FOR FY90**

FINAL REPORT

SEPTEMBER 1991

Version 3.1
Volume II

Prepared by:

**R. L. STOLLAR & ASSOCIATES INC.
HARDING LAWSON ASSOCIATES
EBASCO SERVICES INC.
DATACHEM, INC.
MIDWEST RESEARCH INSTITUTE**

Prepared for:

**U. S. ARMY PROGRAM MANAGER FOR
ROCKY MOUNTAIN ARSENAL**

DTIC QUALITY INSPECTED 3

THE VIEWS, OPINIONS, AND/OR FINDINGS CONTAINED IN THIS REPORT ARE THOSE OF THE AUTHOR(S) AND SHOULD NOT BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION, POLICY, OR DECISION, UNLESS SO DESIGNATED BY OTHER DOCUMENTATION.


THE USE OF TRADE NAMES IN THIS REPORT DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS. THE REPORT MAY NOT BE CITED FOR PURPOSES OF ADVERTISEMENT.

PRINTED ON RECYCLED PAPER

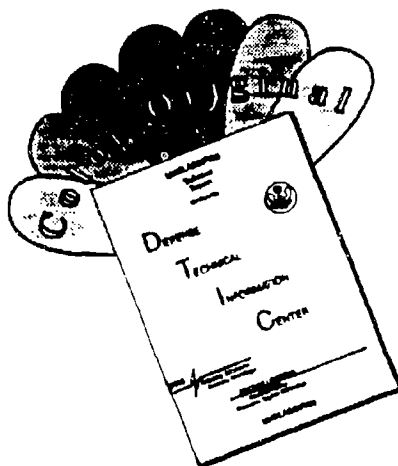
REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE 09/00/91		3. REPORT TYPE AND DATES COVERED FINAL	
4. TITLE AND SUBTITLE COMPREHENSIVE MONITORING PROGRAM, FINAL AIR QUALITY DATA ASSESSMENT REPORT FOR FY90, VERSION 3.1 Vol 2				5. FUNDING NUMBERS NONE	
6. AUTHOR(S)					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) ROBERT L. STOLLAR AND ASSOCIATES				8. PERFORMING ORGANIZATION REPORT NUMBER 91311R01	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSERIN/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES NONE					
12a. DISTRIBUTION/AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) THE OBJECTIVE OF THIS CMP IS TO: VERIFY AND EVALUATE POTENTIAL AIR QUALITY HEALTH HAZARDS, TO VERIFY PROGRESS THAT HAS BEEN MADE TO DATE IN REMOVING CONTAMINANTS RESULTING FROM PREVIOUS ACTIVITIES, TO PROVIDE BASELINE DATA FOR THE EVALUATION OF PROGRESS THAT WILL BE MADE IN FUTURE REMEDIAL ACTIVITIES, TO DEVELOP REAL-TIME GUIDELINES, STANDARD PROCEDURES AND DATA COLLECTION METHODS, AS APPROPRIATE, TO INDICATE IMPACTS OF ONGOING, REMEDIAL ACTIONS, AND TO VALIDATE AND DOCUMENT DATABASE RELIABILITY. <div style="text-align: center;"> <p>96-01807</p>  <p>A-1 9 6 9 09 504</p> </div>					
14. SUBJECT TERMS CONTAMINANT SOURCES, HEALTH AND SAFETY, METEOROLOGY				15. NUMBER OF PAGES 4 VOLS.	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT		20. LIMITATION OF ABSTRACT	

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF COLOR PAGES WHICH DO NOT REPRODUCE LEGIBLY ON BLACK AND WHITE MICROFICHE.

COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-0095

**AIR QUALITY DATA ASSESSMENT REPORT
FOR FY90**

FINAL REPORT

SEPTEMBER 1991

Version 3.1
Volume II

Prepared by:

**R. L. STOLLAR & ASSOCIATES INC.
HARDING LAWSON ASSOCIATES
EBASCO SERVICES INC.
DATACHEM, INC.
MIDWEST RESEARCH INSTITUTE**

Prepared for:

**U. S. ARMY PROGRAM MANAGER FOR
ROCKY MOUNTAIN ARSENAL**

DTIC QUALITY INSPECTED 3

THE VIEWS, OPINIONS, AND/OR FINDINGS CONTAINED IN THIS REPORT ARE THOSE OF THE AUTHOR(S) AND SHOULD NOT BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION, POLICY, OR DECISION, UNLESS SO DESIGNATED BY OTHER DOCUMENTATION.

THE USE OF TRADE NAMES IN THIS REPORT DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS. THE REPORT MAY NOT BE CITED FOR PURPOSES OF ADVERTISEMENT.

PRINTED ON RECYCLED PAPER

TABLE OF CONTENTS

PAGE

VOLUME I

EXECUTIVE SUMMARY	1
1.0 INTRODUCTION	1
1.1 SITE BACKGROUND INFORMATION	4
1.2 POTENTIAL CONTAMINANT SOURCES	4
1.2.1 SOUTH PLANTS MANUFACTURING COMPLEX	8
1.2.2 BASIN A	8
1.2.3 BASIN F	9
1.2.3.1 Background of Previous Studies	9
1.2.3.2 Impacts of Basin F Remediation on CMP	10
1.2.4 OTHER POTENTIAL CONTAMINANT SOURCE AREAS	10
1.2.5 FINDINGS OF THE AIR REMEDIAL INVESTIGATION PROGRAM	11
1.2.6 RESULTS OF THE CMP FY88 AND FY89 ASSESSMENTS	12
2.0 REGIONAL AND LOCAL AIR QUALITY AND METEOROLOGICAL CHARACTERISTICS	15
2.1 AIR QUALITY	15
2.1.1 PARTICULATES	15
2.1.2 METALS	19
2.1.3 SULFUR DIOXIDE	19
2.1.4 NITROGEN OXIDES	20
2.1.5 OZONE	21
2.1.6 CARBON MONOXIDE	21
2.2 METEOROLOGY AND AIR QUALITY DISPERSION	22
3.0 PROGRAM STRATEGY AND METHODOLOGY	30
3.1 GENERAL BACKGROUND	30
3.2 CMP AIR QUALITY MONITORING PROGRAM	31
3.2.1 SITING CRITERIA	32
3.2.1.1 Proximity to Sources or Boundaries	32
3.2.1.2 Wind Speed/Direction	32
3.2.1.3 Topographical Features and Obstructions	39
3.2.1.4 Continuity With Previous Monitoring Programs	39
3.2.2 THE CMP AIR QUALITY MONITORING NETWORK LOCATIONS	40
3.2.2.1 Permanent Stations Locations	40
3.2.2.2 Portable Air Quality Monitoring Stations	40
3.2.3 AIR QUALITY MONITORING STRATEGIES	41
3.2.3.1 Baseline Assessment	41

TABLE OF CONTENTS (continued)

	PAGE
3.2.3.2 Worst-case Assessment	44
3.2.3.3 Remedial Assessment	45
3.2.3.4 Criteria for Gaseous Pollutant Assessment	45
3.2.4 AIR QUALITY MONITORING METHODS	46
3.2.4.1 Total Suspended Particulates (TSP)	46
3.2.4.2 Particulate Matter Less than 10 Microns (PM-10)	47
3.2.4.3 Asbestos	47
3.2.4.4 Volatile Organic Compounds	47
3.2.4.5 Semi-volatile Organic Compounds	48
3.2.4.6 ICP Metals and Arsenic	48
3.2.4.7 Organochlorine Pesticides (OCP)	49
3.2.4.8 Mercury	49
3.3 THE BASIN F REMEDIATION AIR MONITORING PROGRAM	49
3.4 THE IRA-F AIR QUALITY MONITORING PROGRAM	52
3.4.1 SAMPLING LOCATIONS	52
3.4.2 SAMPLING STRATEGY	52
3.4.3 CAP AND VENT MONITORING	55
3.5 METEOROLOGICAL MONITORING PROGRAM	55
3.5.1 LOCATION OF METEOROLOGICAL MONITORING STATIONS	55
3.5.2 MONITORING EQUIPMENT AND STRATEGY	57
3.5.3 DATA ACQUISITION	57
3.5.4 DATA APPLICATIONS	58
3.6 CONTINUOUS AIR MONITORING PROGRAM	59
3.7 LABORATORY ANALYSIS PROGRAM	59

VOLUME II

4.0 RESULTS OF FY90 PROGRAM	64
4.1 BASIS OF AIR QUALITY DATA EVALUATION	64
4.1.1 COMPUTERIZED DOCUMENTATION	65
4.1.2 REMEDIATION EVALUATION	67
4.1.3 DISPERSION MODEL APPLICATIONS	68
4.1.4 SOURCE EMISSION FACTORS	74
4.2 TOTAL SUSPENDED PARTICULATES (TSP)	75
4.2.1 CMP FY90 TSP RESULTS	75
4.2.2 ASSESSMENT OF BASIN F TSP POST-REMEDIATION IMPACTS	88
4.2.2.1 CMP TSP Monitoring Results	88
4.2.2.2 Basin F TSP Monitoring Results	96
4.2.2.3 Analysis of Combined CMP/Basin F TSP Monitoring Results	105
4.2.2.4 Individual Day Remedial Assessment Comparisons	110

TABLE OF CONTENTS (continued)

	PAGE
4.2.3 RMA TSP CAUSAL EFFECTS	110
4.2.4 DENVER METROPOLITAN AREA TSP INFLUENCES	120
4.2.4.1 CMP FY90 Period Results	120
4.2.5 ANALYSIS IMPLICATIONS FOR MITIGATION AND CONTROLS	125
4.2.6 SUMMARY	126
4.3 RESPIRABLE PARTICULATE MATTER	126
4.3.1 CMP PM-10 MONITORING PROGRAM	126
4.3.2 BASIN F PM-10 IMPACTS	129
4.3.2.1 CMP Data	129
4.3.2.2 Basin F Data	140
4.3.2.3 Combined Basin F and CMP Data Analysis	140
4.3.3 METROPOLITAN DENVER PM-10 DATA	144
4.3.4 SUMMARY OF PM-10 ANALYSIS	147
4.4 METALS	147
4.4.1 METALS MONITORING STRATEGIES	147
4.4.2 CMP FY90 METALS MONITORING RESULTS	148
4.4.3 ASSESSMENT OF BASIN F METALS IMPACTS	152
4.4.3.1 CMP Data	152
4.4.3.2 Basin F Data	159
4.4.3.3 Combined CMP and Basin F Data Analyses	173
4.4.4 ANALYSIS OF METALS SOURCE FACTORS	180
4.4.5 ASSESSMENT OF METALS CONCENTRATIONS RELATIVE TO TOXIC GUIDELINES	188
4.4.6 SUMMARY	191
4.5 ASBESTOS	191
4.6 VOLATILE ORGANIC COMPOUNDS (VOCs)	192
4.6.1 CMP VOC SAMPLING, ANALYSIS AND REPORTING STRATEGIES	192
4.6.2 CMP FY90 VOC MONITORING RESULTS	194
4.6.2.1 December 19, 1989	200
4.6.2.2 June 27, 1990	202
4.6.2.3 July 18, 1990	202
4.6.2.4 July 27, 1990	206
4.6.2.5 August 9, 1990	208
4.6.2.6 September 11, 1990	210
4.6.3 BASIN F VOC IMPACTS	210
4.6.3.1 CMP Data	210
4.6.3.2 Basin F Data	221
4.6.3.3 Combined CMP and Basin F Data Analyses	238

TABLE OF CONTENTS (continued)

	PAGE
4.6.4 ADDITIONAL VOC MONITORING CONSIDERATIONS	244
4.6.4.1 Seasonal VOC Impacts	244
4.6.4.2 Metropolitan Denver Area VOC Emissions	247
4.6.5 SUMMARY OF RESULTS AND ASSESSMENT OF VOC TOXICITY LEVELS	256
4.6.6 VOC NONTARGET ANALYTE RESULTS	266
4.6.6.1 Laboratory Procedures	266
4.6.6.2 Summary of Nontarget VOCs	267
4.7 SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs) AND ORGANOCHLORINE PESTICIDES (OCPs)	272
4.7.1 MONITORING, ANALYSIS AND REPORTING STRATEGIES	272
4.7.2 CMP FY90 SEMI-VOLATILE ORGANIC COMPOUNDS MONITORING RESULTS	274
4.7.2.1 August 2, 1990	277
4.7.2.2 August 7, 1990	280
4.7.2.3 August 29, 1990	280
4.7.3 BASIN F SVOC IMPACTS	284
4.7.3.1 CMP Data	284
4.7.3.2 Basin F Data	288
4.7.3.3 Combined CMP and Basin F Data Analyses	300
4.7.4 SUMMARY OF RESULTS AND ASSESSMENT OF SVOC TOXICITY LEVELS	305
4.7.5 SEASONAL CONSIDERATIONS	310
4.7.6 SVOC NONTARGET ANALYTE RESULTS	310

VOLUME III

5.0 CONTINUOUS AIR MONITORING PROGRAM	318
5.1 PROGRAM OVERVIEW	318
5.2 ANALYSIS OVERVIEW	321
5.3 CARBON MONOXIDE	321
5.4 OZONE	332
5.5 SULFUR DIOXIDE	341
5.6 NITRIC OXIDE, NITROGEN DIOXIDE AND NITROGEN OXIDES	351
5.7 REGIONAL EMISSION SOURCES IMPACTING RMA	376
5.7.1 DECEMBER 22-23, 1989	381
5.7.2 MAY 21, 1990	384
6.0 PHOTO VISIBILITY STUDY	393
6.1 HIGH WIND DUST EVENTS	394
6.2 BROWN CLOUD EVENTS	398
6.3 SUMMARY	418
7.0 METEOROLOGY MONITORING AND DISPERSION MODELING PROGRAMS	419

TABLE OF CONTENTS (continued)

	PAGE
7.1 METEOROLOGY PROGRAM OVERVIEW	419
7.1.1 PROGRAM OBJECTIVES	419
7.1.2 DATA RECOVERY	420
7.1.3 DATABASES	420
7.2 SUMMARY OF RESULTS	421
7.2.1 TEMPERATURE	424
7.2.2 RELATIVE HUMIDITY	424
7.2.3 BAROMETRIC PRESSURE	426
7.2.4 SOLAR RADIATION	426
7.2.5 PRECIPITATION	426
7.2.6 WINDS	428
7.2.7 ATMOSPHERIC STABILITY	428
7.3 SEASONAL AND DIURNAL INFLUENCES	435
7.4 SUMMARY AND CONCLUSIONS	441
7.5 RMA METEOROLOGICAL STATION COMPARISONS	443
7.6 ATMOSPHERIC DISPERSION MODEL	448
7.6.1 MODEL APPLICATIONS	448
7.6.2 ADDITIONAL MODEL APPROACHES AND ANALYSES	452
7.6.2.1 Source Emissions Characterization	452
7.6.2.2 Remedial Activity Production Data	452
7.6.2.3 Local and Regional Emissions Inventory	453
7.6.2.4 Empirical/Statistical Adjustments	453
8.0 QUALITY ASSURANCE PROGRAM	454
8.1 OVERVIEW AND GENERAL GUIDANCE	454
8.2 LABORATORY QUALITY CONTROL AND QUALITY ASSURANCE PROGRAM OVERVIEW ..	455
8.3 FIELD QUALITY CONTROL PROGRAM	457
8.3.1 ORGANIZATION	457
8.3.2 FIELD PROGRAM QUALITY CONTROL	457
8.3.3 QUALITY CONTROL FIELD SAMPLE RESULTS	458
8.3.3.1 VOC Quality Control Results	458
8.3.3.2 Semi-Volatile Organics and Organics on PUF Quality Control Results	459
8.3.4 DATA PROCESSING	463
8.4 ASSESSMENT OF DATA PRECISION AND COLLOCATED DUPLICATE SAMPLING RESULTS	464
8.5 QUALITY ASSURANCE FIELD PROCEDURES	469
8.5.1 SYSTEM AUDITS	470
8.5.2 PERFORMANCE AUDITS OF FIELD SAMPLING EQUIPMENT	470
8.5.3 CALIBRATION AND CERTIFICATION OF STANDARDS	471
9.0 CONCLUSIONS	472

TABLE OF CONTENTS (continued)

	PAGE
9.1 TOTAL SUSPENDED PARTICULATES	472
9.2 RESPIRABLE PARTICULATES (PM-10)	473
9.3 METALS	473
9.4 ASBESTOS	473
9.5 VOLATILE ORGANIC COMPOUNDS	473
9.6 SEMI-VOLATILE ORGANIC COMPOUNDS	474
9.7 ORGANOCHLORINE PESTICIDES	474
9.8 CRITERIA POLLUTANTS	474
9.9 GENERAL INTERPRETATIONS	474
10.0 REFERENCES	476

VOLUME IV

APPENDIX A	Total Suspended Particulates (TSP) Data (on diskette)
APPENDIX B	Respirable Particulates of Less Than 10 Microns (PM-10) Data (on diskette)
APPENDIX C	Arsenic, Metals and Mercury Data (on diskette)
APPENDIX D	Asbestos Data (on diskette)
APPENDIX E	Volatile Organic Compounds (VOC) Data (on diskette)
APPENDIX F	Semi-Volatile Organic Compounds (SVOC) Data (on diskette)
APPENDIX G	Organochlorine Pesticides (OCP) Data (on diskette)
APPENDIX H	Quality Assurance/Quality Control
APPENDIX I	Continuous Air Quality Data
APPENDIX J	Air Quality Meteorological Data and Joint Frequency Distribution (on diskette)
APPENDIX K	ISC and INPUFF2 EPA Model Description
APPENDIX L	IRA-F Total Suspended Particulates (TSP) Data (on diskette)
APPENDIX M	IRA-F Respirable Particulates of Less Than 10 Microns (PM-10) (on diskette)
APPENDIX N	IRA-F Arsenic, Metals, and Mercury Data (on diskette)
APPENDIX O	IRA-F Volatile Organic Compounds (VOC) Data (on diskette)
APPENDIX P	IRA-F Semi-Volatile Organic Compounds (SVOC) Data (on diskette)
APPENDIX Q	IRA-F Organochlorine Pesticides (OCP) Data (on diskette)

LIST OF TABLES

Table 2.1-1	Colorado and National Ambient Air Quality Standards
Table 2.2-1	Summary of Temperature Data in the RMA Vicinity
Table 2.2-2	Summary of Precipitation and Humidity Data in the RMA Vicinity
Table 2.2-3	Summary of Wind and Pressure Data in the RMA Vicinity
Table 2.2-4	Summary of Meteorological Data in the RMA Vicinity
Table 3.2-1	Sampling Locations
Table 3.2-2	Parameters and Strategies for RMA Air Monitoring Program
Table 3.2-3	Sampling Strategies for High Event Air Quality Monitoring
Table 3.4-1	Location and Monitoring Parameters at IRA-F Sites
Table 3.5-1	Meteorological Parameters Monitored at RMA During FY90
Table 3.6-1	RMA Continuous Gaseous Air Monitoring Program Summary
Table 3.7-1	Analytical Methods for Air Quality Monitoring Program
Table 3.7-2	Analytes and Certified Reporting Limits for Air Quality Monitoring Program
Table 4.1-1	Basin F Remediation Phases
Table 4.1-2	Emissions Inventory Summary for Regulated Pollutants
Table 4.2-1	Summary of RMA Total Suspended Particulates (TSP) Monitoring for FY90
Table 4.2-2	Total Suspended Particulates (TSP) Sampling Results for FY90
Table 4.2-3	Total Suspended Particulates (TSP) Sampling Results for CMP Phases 1-4
Table 4.2-4	Total Suspended Particulates (TSP) Sampling Results for Basin F/IRA-F Phases 1-4
Table 4.2-5	Combined Seasonal TSP Concentrations
Table 4.2-6	Seasonal TSP Concentrations by Site
Table 4.2-7	Particulate Sources with Emissions of 25 TPY or More
Table 4.2-8	Denver Metropolitan Area Total Suspended Particulates (TSP)
Table 4.3-1	Summary of CMP FY90 Sampling for Respirable Particulates of Less Than 10 Microns (PM-10)
Table 4.3-2	Concentrations of Respirable Particulates of Less Than 10 Microns (PM-10) for CMP FY90

LIST OF TABLES (continued)

Table 4.3-3	Concentrations of Respirable Particulates of Less Than 10 Microns (PM-10) for Phases 1-4
Table 4.3-4	Combined Seasonal PM-10 Concentrations
Table 4.3-5	Seasonal PM-10 Concentrations by Site
Table 4.3-6	Concentrations of Respirable Particulates of Less Than 10 Microns for Phases 3 and 4 at IRA-F Sites
Table 4.3-7	Denver Metropolitan Area Respirable Particulates of Less Than 10 Microns (PM-10)
Table 4.4-1	Summary of Routine Metals Sampling for FY90
Table 4.4-2	Summary of CMP Metals Concentrations for FY90
Table 4.4-3	Summary of CMP Metals Concentrations by Phase
Table 4.4-4	Metals Data Summary for 1986-1987 Remedial Investigation Program
Table 4.4-5	Summary of Basin F/IRA-F/RIFS Metals Concentrations for Phases 1-4
Table 4.4-6	Observed Maximum Metals Concentrations and Associated Wind Speed at CMP Sites
Table 4.4-7	Seasonal Metals and Arsenic Concentrations by Site
Table 4.4-8	Maximum Concentrations Measured at RMA for CMP and Basin F/IRA-F Concurrent Programs
Table 4.4-9	RMA Target Metals Compounds Comparison to Health Guidelines
Table 4.5-1	Synopsis of FY90 Asbestos Monitoring
Table 4.6-1	Synopsis of FY90 Monitoring for Volatile Organic Compounds (VOC)
Table 4.6-2	Summary of FY90 Volatile Organic Compounds (VOC) Concentrations
Table 4.6-3	Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4
Table 4.6-4	Summary of Basin F/IRA-F/RIFS VOC Concentrations for Phases 1-4
Table 4.6-5	Maximum Concentrations and Locations of Volatile Organic Compounds
Table 4.6-6	Combined Seasonal Average VOC Concentrations
Table 4.6-7	Volatile Organic Compounds (VOC) Sources with Emissions of 10 TPY or More
Table 4.6-8	Total Releases of Toxic Chemicals by Facility and Toxicity for Denver and Adams Counties
Table 4.6-9	Releases of Toxic Chemicals for Denver and Adams Counties

LIST OF TABLES (continued)

Table 4.6-10	RMA Target Volatile Organic Compounds (VOC) Comparison to Health Guidelines for Phases 1 and 2
Table 4.6-11	RMA Target Volatile Organic Compounds (VOC) Comparison to Health Guidelines for Phases 3 and 4
Table 4.6-12	Comparison of EPA Air Toxics Study and RMA Results for VOCs
Table 4.6-13	Ambient Volatile Organic Compounds (VOC) Concentrations from Various Studies
Table 4.6-14	Summary of VOC Nontargets for FY90
Table 4.6-15	Summary of VOC Blank Nontargets for FY90
Table 4.7-1	Synopsis of FY90 Semi-Volatile Organic Compounds (SVOC) Monitoring
Table 4.7-2	Synopsis of FY90 Organochlorine Pesticides (OCP) Monitoring
Table 4.7-3	Summary of Semi-Volatile Organic Compounds (SVOC) Concentrations for FY90 - Pesticide Method
Table 4.7-4	Summary of Organochlorine Pesticides (OCP) Concentrations for FY90
Table 4.7-5	Summary of CMP Semi-Volatile Organic Compounds (SVOC) Concentrations by Phase
Table 4.7-6	Summary of CMP Organochlorine Pesticides (OCP) Concentrations by Phase
Table 4.7-7	Summary of Basin F/IRA-F/RIFS Semi-Volatile Organic Compounds (SVOC) by Phases 1-4
Table 4.7-8	Maximum Average Long-Term and Short-Term Semi-Volatile Organic Compounds Concentrations
Table 4.7-9	RMA Target SVOC and OCP Comparison to Health Guidelines
Table 4.7-10	Combined Seasonal Organochlorine Pesticides (OCP) Concentrations
Table 4.7-11	Summary of SVOC Nontargets for FY90
Table 4.7-12	Summary of SVOC Nontargets Blank Data for FY90
Table 5.1-1	RMA and Colorado Department of Health Gaseous Emissions Monitoring Sites
Table 5.3-1	Summary of Carbon Monoxide 1-Hour Average Values in ppm October 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)
Table 5.3-2	Summary of Carbon Monoxide 8-Hour Average Values in ppm October 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)
Table 5.4-1	Summary of Ozone 1-Hour Average Values in ppm October 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)

LIST OF TABLES (continued)

Table 5.5-1	Summary of Sulfur Dioxide 1-Hour Average Values in ppm October 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)
Table 5.5-2	Summary of Sulfur Dioxide 3-Hour Average Values in ppm October 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)
Table 5.5-3	Summary of Sulfur Dioxide 24-Hour Average Values in ppm October 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)
Table 5.6-1	Summary of Nitric Oxide (NO) 1-Hour Average Values in ppm October 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)
Table 5.6-2	Summary of Nitrogen Dioxide (NO ₂) 1-Hour Average Values in ppm October 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)
Table 5.6-3	Summary of Nitrogen Oxides (NO _x) 1-Hour Average Values in ppm October 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)
Table 5.7-1	Carbon Monoxide (CO) Sources with Emissions of 100 TPY or More
Table 5.7-2	Sulfur Dioxide (SO ₂) Sources with Emissions of 40 TPY or More
Table 5.7-3	Nitrogen Oxides (NO _x) Sources with Emissions of 40 TPY or More
Table 5.7-4	Relevant Air Quality and Meteorological Data for December 22-23, 1989
Table 5.7-5	Relevant Air Quality and Meteorological Data for May 21, 1990
Table 6.1-1	Summary of High Dust Events During FY90
Table 6.1-2	TSP Monitoring Results for May 15, 1990
Table 6.1-3	May 15, 1990 Dust Event Data
Table 6.2-1	October 25, 1989 Brown Cloud Event Data
Table 6.2-2	January 5, 1990 Brown Cloud Event Data
Table 6.2-3	September 14, 1990 Brown Cloud Event Data
Table 7.1-1	Summary of RMA Meteorological Monitoring for FY90
Table 7.2-1	Summary of Rocky Mountain Arsenal Monthly Meteorological Conditions for FY90 (October 1, 1989 through September 30, 1990)
Table 7.4-1	FY89 - FY90 Comparison
Table 7.5-1	Meteorological Tower Comparison of Wind Speed (mph)/Direction
Table 7.5-2	Meteorological Tower Comparison of Temperature (°F)
Table 7.5-3	Meteorological Tower Comparison of Precipitation (inches)
Table 7.5-4	FY90 Frequency (%) of Atmospheric Stability Categories for Each Met Station

LIST OF TABLES (continued)

Table 8.3-1	CMP Target Volatile Organic Compounds (VOC) Blank Values
Table 8.3-2	Summary of Semi-Volatile Organic Compounds Results of Field Spiking
Table 8.3-3	Summary of OCP Results of Field Spiking
Table 8.4-1	Collocated Sample Comparisons for FY90 at AQ5
Table 8.4-2	Continuous Air Quality Parameters Precision Results

LIST OF FIGURES

Figure 1.1-1	Rocky Mountain Arsenal Location Map
Figure 1.1-2	Rocky Mountain Arsenal Reference Map
Figure 1.2-1	CMP Air Quality and Meteorological Monitoring Stations
Figure 2.2-1	Stapleton Airport Wind Direction Rose, 1982-1986
Figure 3.2-1	CMP Air Quality Monitoring Stations at Rocky Mountain Arsenal
Figure 3.2-2	National Ambient Air Quality Sampling Schedule for 1990
Figure 3.3-1	Location of Basin F Air Quality Monitoring Stations at Rocky Mountain Arsenal
Figure 3.4-1	Location of IRA-F Air Quality Monitoring Stations at Rocky Mountain Arsenal
Figure 3.5-1	RMA Meteorological Monitoring Stations
Figure 4.1-1	X/Q Dispersion for Phase 1
Figure 4.1-2	X/Q Dispersion for Phase 2-Stage 1
Figure 4.1-3	X/Q Dispersion for Phase 2-Stage 2
Figure 4.1-4	X/Q Dispersion for Phase 3
Figure 4.1-5	X/Q Dispersion for Phase 4
Figure 4.1-6	Sources of Regulated Pollutants in RMA Vicinity
Figure 4.2-1	CMP Total Suspended Particulates Results for FY90
Figure 4.2-2	TSP Results for 9/14/90
Figure 4.2-3	September 14, 1990 12Z Sounding for Stapleton Airport
Figure 4.2-4	TSP Distribution at RMA for 6/4/90
Figure 4.2-5	TSP Concentrations at AQ10 During Remediation Phases
Figure 4.2-6	Basin F/IRA-F TSP Results by Phase
Figure 4.2-7	Composite TSP Analysis for Phase 1
Figure 4.2-8	Composite TSP Analysis for Phase 4
Figure 4.2-9	TSP Geometric Means by Phase for CMP
Figure 4.2-10	TSP Results for 9/24/88
Figure 4.2-11	TSP Results for 9/26/90

LIST OF FIGURES (continued)

Figure 4.2-12	Site AQ11 TSP Concentrations vs. Hours of Wind from Direction of Basin F - Phase 1
Figure 4.2-13	Site AQ11 TSP Concentrations vs. Hours of Wind from Direction of Basin F - Phase 3
Figure 4.2-14	Particulate Sources with Emissions of 25 TPY or More in RMA Vicinity
Figure 4.2-15	Denver Area TSP Data for FY90 - Geometric Means
Figure 4.3-1	PM-10 Results for 9/14/90
Figure 4.3-2	Comparison of TSP and PM-10 at AQ2
Figure 4.3-3	Comparison of TSP and PM-10 at AQ5
Figure 4.3-4	Comparison of TSP and PM-10 at AQ9
Figure 4.3-5	Composite PM-10 Analysis for Phase 1
Figure 4.3-6	Composite PM-10 Analysis for Phase 4
Figure 4.3-7	Denver Area PM-10 Data for Phase 4
Figure 4.4-1	Chromium Results by Phase
Figure 4.4-2	Copper Results by Phase
Figure 4.4-3	Mercury Results by Phase
Figure 4.4-4	Zinc Results by Phase
Figure 4.4-5	Lead Results by Phase
Figure 4.4-6	Arsenic Results by Phase
Figure 4.4-7	Cadmium Results by Phase
Figure 4.4-8	X/Q Dispersion and Basin F Metals for 9/6/88
Figure 4.4-9	X/Q Dispersion and IRA-F Metals for 6/10/90
Figure 4.4-10	Composite Metals Analysis for Phase 1 - Average Values
Figure 4.4-10A	Composite Metals Analysis for Phase 1 - Maximum Values
Figure 4.4-11	Composite Metals Analysis for Phase 4 - Average Values
Figure 4.4-11A	Composite Metals Analysis for Phase 4 - Maximum Values
Figure 4.4-12	Metals Results and X/Q Dispersion for 6/28/90
Figure 4.6-1	Seasonal VOC Results and X/Q Dispersion for 12/19/89
Figure 4.6-2	High Event VOC Results and X/Q Dispersion for 6/27/90

LIST OF FIGURES (continued)

Figure 4.6-2A	High Event VOC Results for 6/27/90 - South Plants
Figure 4.6-3	High Event VOC Results and X/Q Dispersion for 7/18/90
Figure 4.6-4	High Event VOC Results and X/Q Dispersion for 7/27/90
Figure 4.6-5	High Event VOC Results and X/Q Dispersion for 8/9/90
Figure 4.6-6	High Event VOC Results and X/Q Dispersion for 9/11/90
Figure 4.6-7	Bicycloheptadiene Results by Phase
Figure 4.6-8	Chloroform Results by Phase
Figure 4.6-9	Dicyclopentadiene Results by Phase
Figure 4.6-10	Dimethyl Disulfide Results by Phase
Figure 4.6-11	Toluene Results by Phase
Figure 4.6-12	X/Q Dispersion and Basin F VOCs for 8/12/88
Figure 4.6-13	X/Q Dispersion and IRA-F VOCs for 7/28/90
Figure 4.6-14	Composite VOC Analysis for Phase 1 - Average Values
Figure 4.6-14A	Composite VOC Analysis for Phase 1 - Maximum Values
Figure 4.6-15	Composite VOC Analysis for Phase 4 - Average Values
Figure 4.6-15A	Composite VOC Analysis for Phase 4 - Maximum Values
Figure 4.6-16	VOC Sources with Emissions of 25 TPY or More in RMA Vicinity
Figure 4.7-1	High Event SVOC Results and X/Q Dispersion for 8/2/90
Figure 4.7-2	High Event SVOC Results and X/Q Dispersion for 8/7/90
Figure 4.7-2A	High Event SVOC Results for 8/7/90 - South Plants
Figure 4.7-3	High Event SVOC Results and X/Q Dispersion for 8/29/90
Figure 4.7-4	SVOC Results at CMP/BF2 for Phases 1 and 4
Figure 4.7-5	Aldrin Results by Phase
Figure 4.7-6	Dieldrin Results by Phase
Figure 4.7-7	Endrin Results by Phase
Figure 4.7-8	Isodrin Results by Phase
Figure 4.7-9	X/Q Dispersion and Basin F Pesticides for 8/23/88
Figure 4.7-10	X/Q Dispersion and Basin F Pesticides for 9/8/90

LIST OF FIGURES (continued)

Figure 4.7-11	Composite SVOC Analysis for Phase 1 - Average Values
Figure 4.7-11A	Composite SVOC Analysis for Phase 1 - Maximum Values
Figure 4.7-12	Composite SVOC Analysis for Phase 4
Figure 5.1-1	RMA and Colorado Department of Health Continuous Air Quality Monitoring Sites
Figure 5.3-1A	Graphical Depiction of Daily Mean for Carbon Monoxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.3-1B	Graphical Depiction of Daily Maximum for Carbon Monoxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.3-2	Graphical Depiction of Monthly Mean for Carbon Monoxide (May 1989 - Sept. 1990)
Figure 5.3-3	Graphical Depiction of Diurnal Cycle for Carbon Monoxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.3-4	Graphical Depiction of Diurnal Comparison for Carbon Monoxide (May - September)
Figure 5.3-5	CMP and Colorado Department of Health Sites 1-Hour Carbon Monoxide Values (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.3-6	CMP and Colorado Department of Health Sites 8-Hour Carbon Monoxide Values (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.4-1A	Graphical Depiction of Daily Mean for Ozone FY90 (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.4-1B	Graphical Depiction of Daily Maximum for Ozone FY90 (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.4-2	Graphical Depiction of Monthly Mean for Ozone (May 1989 - Sept. 1990)
Figure 5.4-3	Graphical Depiction of Daily Mean for Ozone (May 6, 1989 - Sept. 30, 1990)
Figure 5.4-4	Graphical Depiction of Diurnal Cycle for Ozone FY90 (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.4-5	Graphical Depiction of Diurnal Comparison for Ozone (May - September)
Figure 5.5-6	Graphical Depiction of Overall Mean for Ozone (May 6, 1989 - Sept. 30, 1990)
Figure 5.4-7	CMP and Colorado Department of Health Sites 1-Hour Ozone Values (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.5-1A	Graphical Depiction of Daily Mean for Sulfur Dioxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)
Figure 5.5-1B	Graphical Depiction of Daily Maximum for Sulfur Dioxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)

LIST OF FIGURES (continued)

- Figure 5.5-2 Graphical Depiction of Monthly Mean for Sulfur Dioxide (May 1989 - Sept. 1990)
- Figure 5.5-3 Graphical Depiction of Daily Mean for Sulfur Dioxide (May 6, 1989 - Sept. 30, 1990)
- Figure 5.5-4 Graphical Depiction of Diurnal Cycle for Sulfur Dioxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.5-5 Graphical Depiction of Diurnal Comparison for Sulfur Dioxide (May - Sept.)
- Figure 5.5-6 Graphical Depiction of Overall Mean for Sulfur Dioxide (May 6, 1989 - Sept. 30, 1990)
- Figure 5.5-7 CMP and Colorado Department of Health Sites 3-Hour Sulfur Dioxide Values (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.5-8 CMP and Colorado Department of Health Sites 24-Hour Sulfur Dioxide Values (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.6-1A Graphical Depiction of Daily Mean for Nitric Oxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.6-1B Graphical Depiction of Daily Mean for Nitrogen Dioxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.6-1C Graphical Depiction of Daily Mean for Nitrogen Oxides FY90 (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.6-2A Graphical Depiction of Daily Maximum for Nitric Oxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.6-2B Graphical Depiction of Daily Maximum for Nitrogen Dioxide FY90 (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.6-2C Graphical Depiction of Daily Maximum for Nitrogen Oxides FY90 (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.6-3A Graphical Depiction of Monthly Mean for Nitric Oxide (May 1989 - Sept. 1990)
- Figure 5.6-3B Graphical Depiction of Monthly Mean for Nitrogen Dioxide (May 1989 - Sept. 1990)
- Figure 5.6-3C Graphical Depiction of Monthly Mean for Nitrogen Oxides (May 1989 - Sept. 1990)
- Figure 5.6-4A Graphical Depiction of Daily Mean for Nitric Oxide (May 6, 1989 - Sept. 30, 1990)
- Figure 5.6-4B Graphical Depiction of Daily Mean for Nitrogen Dioxide (May 6, 1989 - Sept. 30, 1990)
- Figure 5.6-4C Graphical Depiction of Daily Mean for Nitrogen Oxides (May 6, 1989 - Sept. 30, 1990)

LIST OF FIGURES (continued)

- Figure 5.6-5 Graphical Depiction of Diurnal Cycle for Nitrogen Oxides (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.6-6 Graphical Depiction of Diurnal Comparison for Nitrogen Oxides (May - September)
- Figure 5.6-7 Graphical Depiction of Diurnal Mean for Nitrogen Oxides (May 6, 1989 - Sept. 30, 1990)
- Figure 5.6-8 CMP and Colorado Department of Health Sites 24-Hour Nitrogen Dioxide Values (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 5.7-1 Sources of Regulated Pollutants in RMA Vicinity
- Figure 5.7-2 Graphical Depiction of Carbon Monoxide for December 22-23, 1989
- Figure 5.7-3 Graphical Depiction of Sulfur Dioxide for December 22-23, 1989
- Figure 5.7-4 Graphical Depiction of Nitrogen Oxides for December 22-23, 1989
- Figure 5.7-5 Graphical Depiction of Carbon Monoxide for May 21, 1990
- Figure 5.7-6 Graphical Depiction of Sulfur Dioxide for May 21, 1990
- Figure 5.7-7 Graphical Depiction of Nitrogen Oxides for May 21, 1990
- Figure 6.1-1 Dust Event Case Study: May 15, 1990
- Figure 6.1-2 Dust Event: May 15, 1990 (SO₂ and NO_x)
- Figure 6.2-1 Brown Cloud Case Study: October 25, 1990
- Figure 6.2-2 Brown Cloud Migration: October 25, 1989
- Figure 6.2-3 Brown Cloud Event: October 25, 1989 (SO₂ and NO_x)
- Figure 6.2-4 Brown Cloud Event: October 25, 1989 (CO)
- Figure 6.2-5 Brown Cloud Case Study: January 5, 1990
- Figure 6.2-6 Brown Cloud Event: January 5, 1990 (SO₂ and NO_x)
- Figure 6.2-7 Brown Cloud Event: January 5, 1990 (CO)
- Figure 6.2-8 Brown Cloud Case Study: September 14, 1990
- Figure 6.2-9 Brown Cloud Event: September 14, 1990 (SO₂ and NO_x)
- Figure 6.2-10 Brown Cloud Event: September 14, 1990 (CO)
- Figure 7.2-1 RMA Graphical Depiction of Temperature (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 7.2-2 RMA Graphical Depiction of Precipitation (Oct. 1, 1989 - Sept. 30, 1990)
- Figure 7.2-3 RMA Graphical Depiction of Wind Speed and Wind Direction (Oct. 1, 1989 - Sept. 30, 1990)

LIST OF FIGURES (continued)

- Figure 7.2-4** **Wind Roses for RMA (Oct. 1 - Dec. 20, 1989) and Stapleton Airport 1982-86 Fall**
- Figure 7.2-5** **Wind Roses for RMA (Dec. 21, 1989 - March 19, 1990) and Stapleton Airport 1982-86 Winte**
- Figure 7.2-6** **Wind Roses for RMA (March 20 - June 20, 1990) and Stapleton Airport 1982-86 Spring**
- Figure 7.2-7** **Wind roses for RMA (June 21 - Sept. 30, 1990) and Stapleton Airport 1982-86 Summer**
- Figure 7.2-8** **Wind Roses for RMA (Oct. 1, 1989 - Sept. 30, 1990) and Stapleton Airport 1982-86 Annual**
- Figure 7.2-9** **RMA and Stapleton Airport Fall Wind Rose Comparisons**
- Figure 7.2-10** **RMA and Stapleton Airport Winter Wind Rose Comparisons**
- Figure 7.2-11** **RMA and Stapleton Airport Spring Wind Rose Comparisons**
- Figure 7.2-12** **RMA and Stapleton Airport Summer Wind Rose Comparisons**
- Figure 7.2-13** **RMA and Stapleton Airport Annual Wind Rose Comparisons**

ACRONYMS AND ABBREVIATIONS

111TCE	1,1,1-Trichloroethane
112TCE	1,1,2-Trichloroethane
ADI	Acceptable Daily Intake
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-s-trianine
BCHPD	Bicycloheptadiene
C ₆ H ₆	Benzene
CCl ₄	Carbon Tetrachloride
CH ₂ Cl ₂	Methylene Chloride
CHCl ₃	Chloroform
Chlordane	1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methano-1H-indene
CiC ₆ H ₅	Chlorobenzene
CMP FY90	Comprehensive Monitoring Program Fiscal Year 1990
CO	Carbon Monoxide
CRL	Certified Reporting Limit
DBCP	Dibromochloropropane
DCLE11	1,1-Dichloroethane
DCLE12	1,2-Dichloroethane
DCPD	Dicyclopentadiene
DDD	Dichlorodiphenyldichloroethane
DMB12	Dimethylbenzene
DMDS	Dimethyl Disulfide
EPA	Environmental Protection Agency
ETC ₆ H ₅	Ethylbenzene
GC/MS	Gas Chromatography/Mass Spectrometry
GC/ECD	Gas Chromatography/Electron Capture Detection
ICAP	Inductively Coupled Argon Plasma
Malathion	0,0-dimethyl-s-(1,2-dicarboxyethyl) phosphorodithioate
MEC ₆ H ₅	Toluene
MIBK	Methyl Isobutyl Ketone
MST	Mountain Standard Time
NAAQS	National Ambient Air Quality Standards
NATICH	National Air Toxics Information Clearinghouse
NIOSH	National Institute of Occupational Safety and Health
NNDMEA	N-Nitrosodimethylamine
NO _x	Nitrogen Oxides
O ₃	Ozone

ACRONYMS AND ABBREVIATIONS (continued)

OCP	Organochlorine Pesticides
Parathion	Parathion ($C_{10}H_{14}NO_5PS$)
PMRMA	Program Manager Rocky Mountain Arsenal
PM-10	Respirable Particulates less than 10 microns
PPDDE	Dichlorodiphenylethane
PPDDT	Dichlorodiphenyltrichloroethane
SO ₂	Sulfur Dioxide
Supona	2-chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate
SVOC	Semi-Volatile Organic Compounds
T12DCE	Trans-1,2-Dichloroethene
TCLEE	Tetrachloroethene
TLV	threshold limit value
tpy	tons per year
TRCLE	Trichloroethene
TSP	Total Suspended Particulates
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USAEHA	U.S. Army Environmental Hygiene Agency
VOC	Volatile Organic Compounds
XYLENE	Xylene

4.0 RESULTS OF FY90 PROGRAM

4.1 BASIS OF AIR QUALITY DATA EVALUATION

The purpose of the Air Monitoring Task of the CMP is to establish an ongoing baseline that can be used to verify ambient air quality at RMA and can be used as a guide to evaluate progress being made in remedial actions. As specified in the Technical Plan, the program has several related key objectives as follows:

- Verify and evaluate potential air quality health hazards that may exist within the RMA boundaries;
- Verify progress that has been made to date in removing potential air contaminants resulting from previous activities;
- Establish a database that can be augmented to verify progress made in future remedial activities;
- Provide real-time guidelines, standardized procedures and data, as appropriate, to indicate impacts of ongoing remedial activities;
- Extend the rigorous database for further use at RMA; and
- Describe potential impacts of other sources of air pollutants.

Both the data monitoring programs and the data verification and evaluation programs have been directed towards these objectives. To the extent possible, the data analyses have been related to causative factors associated with contaminants detected. This requires that consideration be given to a number of variables unique to air quality assessment:

- Transient meteorological conditions: parameters such as wind direction, wind speed, atmospheric stability, inversions, temperature and precipitation;
- RMA land disturbances: in particular, remedial construction and excavation activities;

- Natural surroundings including topography, soil types and vegetation; and
- Ambient contaminant levels directly upwind from the RMA area, and in particular, metropolitan Denver.

In summary, measured background levels of TSP, PM-10, metals, VOC, SVOC and asbestos within RMA cannot be evaluated in terms of the stated objectives without identifying causative and contributing factors including off-Arsenal sources. Consequently, a computer database matrix of ambient concentrations and significant influencing parameters has been established. As the database is expanded over several years, it will have increasing statistical significance and additional applications. For example, if ambient levels of parameters show decreasing concentration levels under similar meteorological and terrain activity conditions, this would indicate either that progress is being made in remedial activities or that the natural depletion of the contaminant is taking place. If no change in conditions is evident and contaminant levels are above normal background expectations, this would confirm the persistence of a given element and/or indicate the ineffectiveness of remedial actions and the need for additional or alternate mitigating actions.

As another example, during the FY90 period, a full year of data was collected in the vicinity of Basin F under both the CMP and IRA-F programs. In this report, these post-remedial data are compared with data collected at identical monitoring sites (and under similar meteorological and climatological conditions) during the Basin F remediation period. The basis of this evaluation will be discussed further in Section 4.1.2.

4.1.1 COMPUTERIZED DOCUMENTATION

Computerized documentation and analysis have provided the following information for this Air Quality Data Assessment Report:

- For each sampling station, a list including the compounds detected at that station, the range of concentrations reported, the maximum concentration, pertinent weather conditions and other causative factors (i.e., close-by remedial activity). High event monitoring activities were similarly documented and reported.
- Comparison of measured TSP, PM-10, metals, arsenic, mercury, asbestos, VOCs, SVOCs, and OCPs with available regional data and with regulatory guidelines,

threshold limit values (TLV), and other air toxic guidelines as appropriate. Comparisons with standards and guidelines are discussed further in this section for each specific group of analytes.

- Comparison of significant (high or low) contaminant levels under similar causative conditions to indicate remedial progress or lack of progress. As basic examples, VOC and SVOC values at an RMA site over a particular season could result from remedial activity, infusions from outside the Arsenal, or specific meteorological conditions. Similarly, high metals levels could result from strong wind speeds from a persistent direction, infusions from Denver, significant excavation activities, or all of the above concurrently. The computer matrix compiled over the life of the CMP delineates these causative relationships for this and future reports.
- Identification of meteorological conditions, excavation activities, or discrete sources and influences that may trigger high levels of contaminant activity and require special precautions and mitigating actions.

In addition, this CMP Air Quality Data Assessment Report for FY90 provides, for the purpose of remediation assessment, the results of the Interim Action Basin F Cleanup Program from the initiation of remedial activities at Basin F in 1988, through September 30, 1990. Evaluation of those data includes the following by-products:

- Incorporation of all remedial activity monitoring data into the CMP, and assessment of these data as a subset of the overall database; and
- Specific standardized guidelines and criteria for air monitoring support of excavation and remedial activities at RMA. Criteria have been based on available literature, existing state-of-the-art techniques, and direct FY88, FY89 and FY90 experience with air quality monitoring and contaminants of concern at RMA; guidelines include specific instrumentation, monitoring procedures and techniques, real-time prediction and alert procedures, and models relating to Health and Safety.

4.1.2 REMEDIATION EVALUATION

It is noted that during the CMP FY88 and FY89 periods, Basin F remediation activities were in progress from March 22, 1988, to May 4, 1989. The post remediation period from May 5, 1989, to September 30, 1989, continued through the conclusion of CMP FY90. The CMP Basin F Remediation Monitoring Program and follow-on IRA-F data provide results of potential air contaminant levels prior to, during and subsequent to the remediation program, and reflect remedial progress. The results of this assessment are provided in this report under the phases and stages shown in Table 4.1-1. All data shown in tables and figures for FY90 cover the period from October 1, 1989, through September 30, 1990.

Table 4.1-1 Basin F Remediation Phases

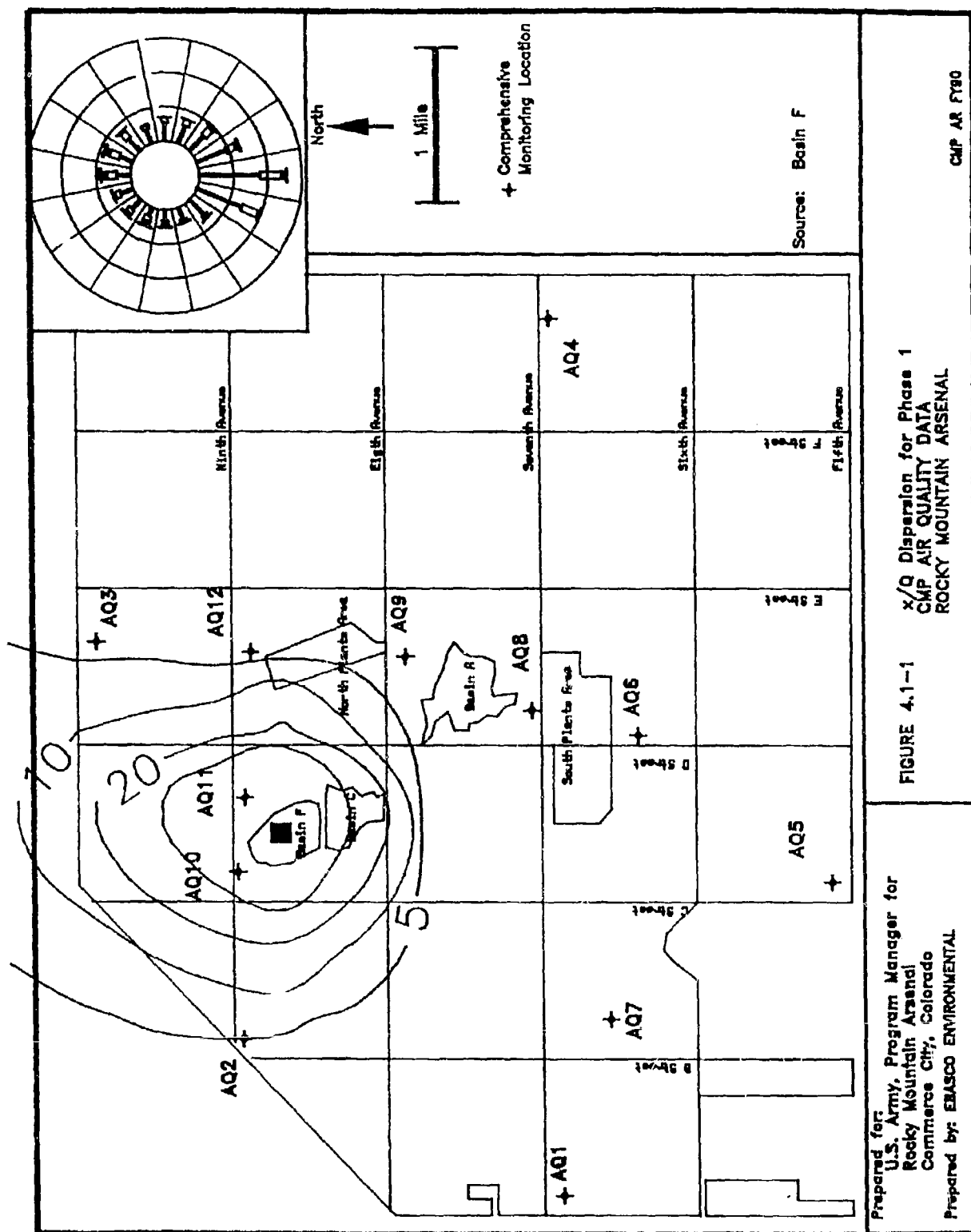
Phase	Dates	Activity	Monitoring Data Available
1	3/22/88 - 12/12/88	Basin F clean-up. Stockpiling of clay for future capping of basin.	CMP FY88, CMP FY89, Basin F Remediation Monitoring Program, RIFS Odor Program
2	(Stage 1) 12/13/88 - 2/15/89 (Stage 2) 2/16/89 - 5/5/89	Capping of basin with clay. Capping of basin with topsoil. Grading and reseedling of basin and surrounding area. Liner installed over holding pond.	CMP FY89, Basin F Remediation Monitoring Program, RIFS Odor Program
3	5/6/89 - 9/30/89	Post-remedial period: Pumping of accumulated waste pile liquids to holding pond.	CMP FY89, IRA-F FY89
4	10/1/89 - 9/30/90	Post-remedial period.	CMP FY90, IRA-F FY90

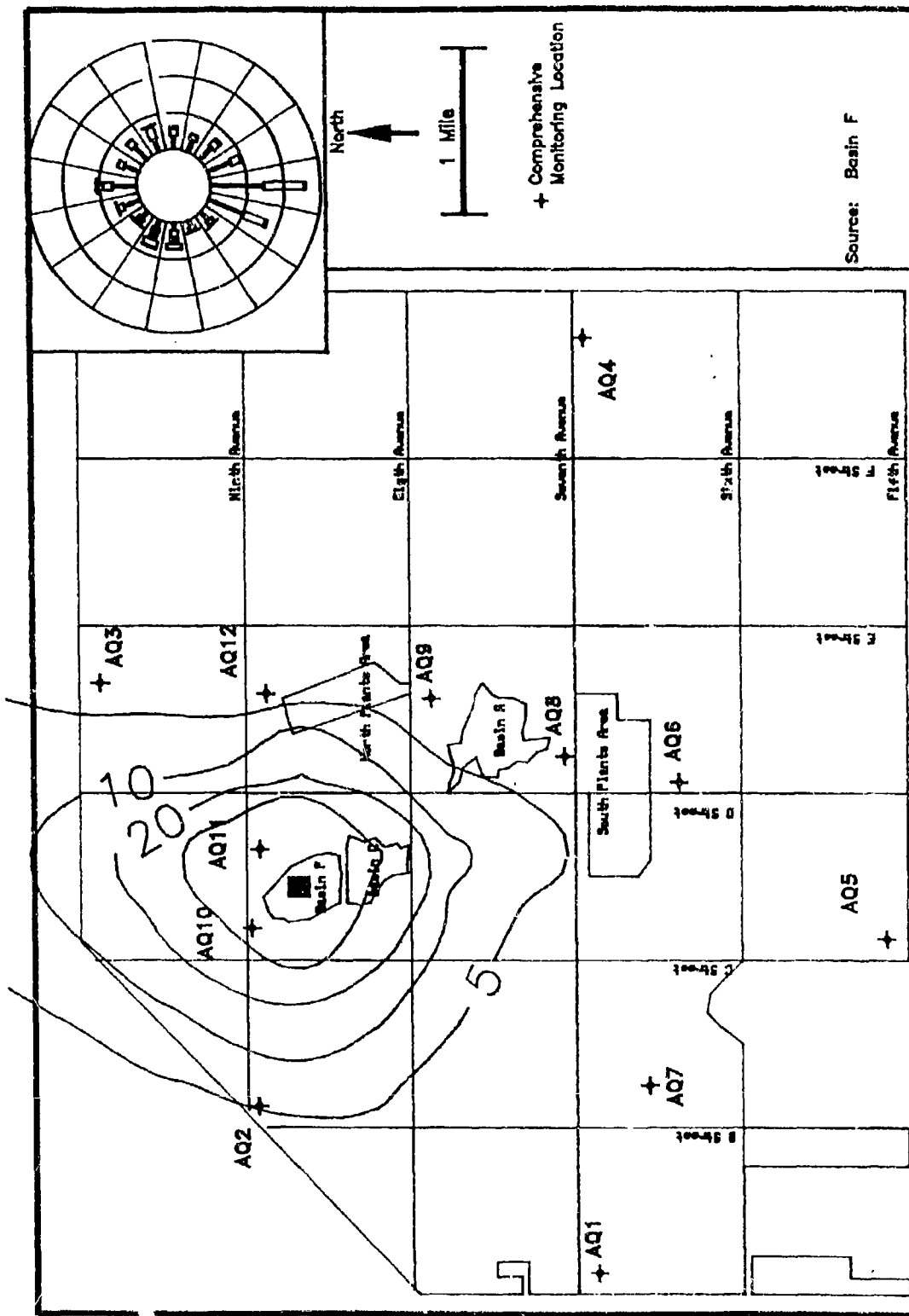
4.1.3 DISPERSION MODEL APPLICATIONS

Finally, the CMP/Basin F Air Quality Modeling Programs have included the development and/or application of several standard and special purpose models for assessing potential contaminant impacts, including the Industrial Source Complex (ISC) Model and a PUFF advection model (USEPA, 1986). Dispersion modeling has assisted appreciably in addressing impacts from potential emission sources, both on and off the Arsenal. During FY88 and FY89, dispersion modeling was employed to evaluate CMP monitored data at Basin F, the South Plants and Basin A. Both the ISC and PUFF Model were also used effectively in the Basin F cleanup program to assess real-time contamination levels during remedial activities and to provide a forewarning of potential hazardous conditions.

In this FY90 Report, which provides a joint analysis of CMP and Basin F data over a 31-month period to evaluate remedial impacts and post-remedial progress, dispersion models were again used to identify both potential source impacts and overriding meteorological factors. One objective for example, is to substantiate that concentrations measured under the remedial phase periods occurred under the influence of typical (and not anomalous) meteorological factors. Figures 4.1-1 through 4.1-5 show mean dispersion patterns for the Phase 1, the Phase 2 Stage 1 and Phase 2 Stage 2 remediation periods, and the Phase 3 and Phase 4 post-remediation periods for an area source centered at Basin F. The dispersion patterns shown here directly influence the sampling results for each of the CMP and Basin F parameters measured during the remediation assessment periods. A brief description of these dispersion patterns is provided below.

The dispersion pattern, or X/Q contours, can be best depicted as a function which relates ambient concentration X, to source strength, Q; thus incorporating all meteorological factors but not including any actual source measurements. The X/Q contours were obtained from the EPA ISC Model (using Basin F as a hypothetical area source); they reflect the influences of wind speed, wind direction, atmospheric stability, and inversion conditions on the spread of pollutants for the monitoring period for each phase. The X/Q values do not indicate actual ambient concentrations, but indicate relative strength, or potential for concentration levels, based on meteorological conditions and an unspecified source strength. Nevertheless, actual higher concentration levels generally correspond to higher X/Q values when there is a significant source impact. As can be seen during Phases 1 and 2, the higher X/Q values are close to the Basin F source and directly downwind from prevailing wind patterns. The dispersion patterns are also skewed to the north of Basin F, reflecting the prevailing flow during the monitoring periods; this is also clearly shown in the wind rose insert for each figure. As a consequence of these dispersion and meteorological patterns, one might anticipate higher



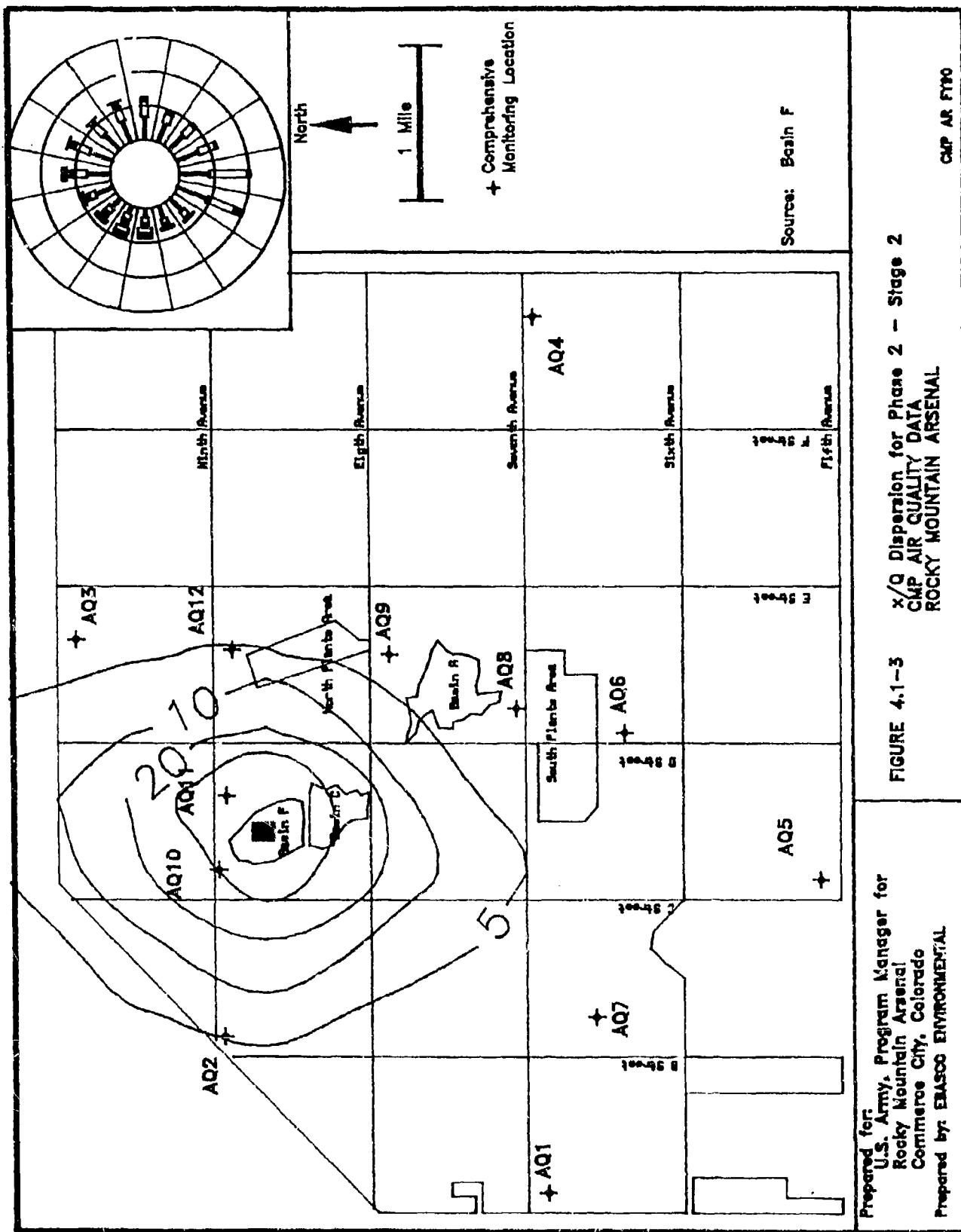


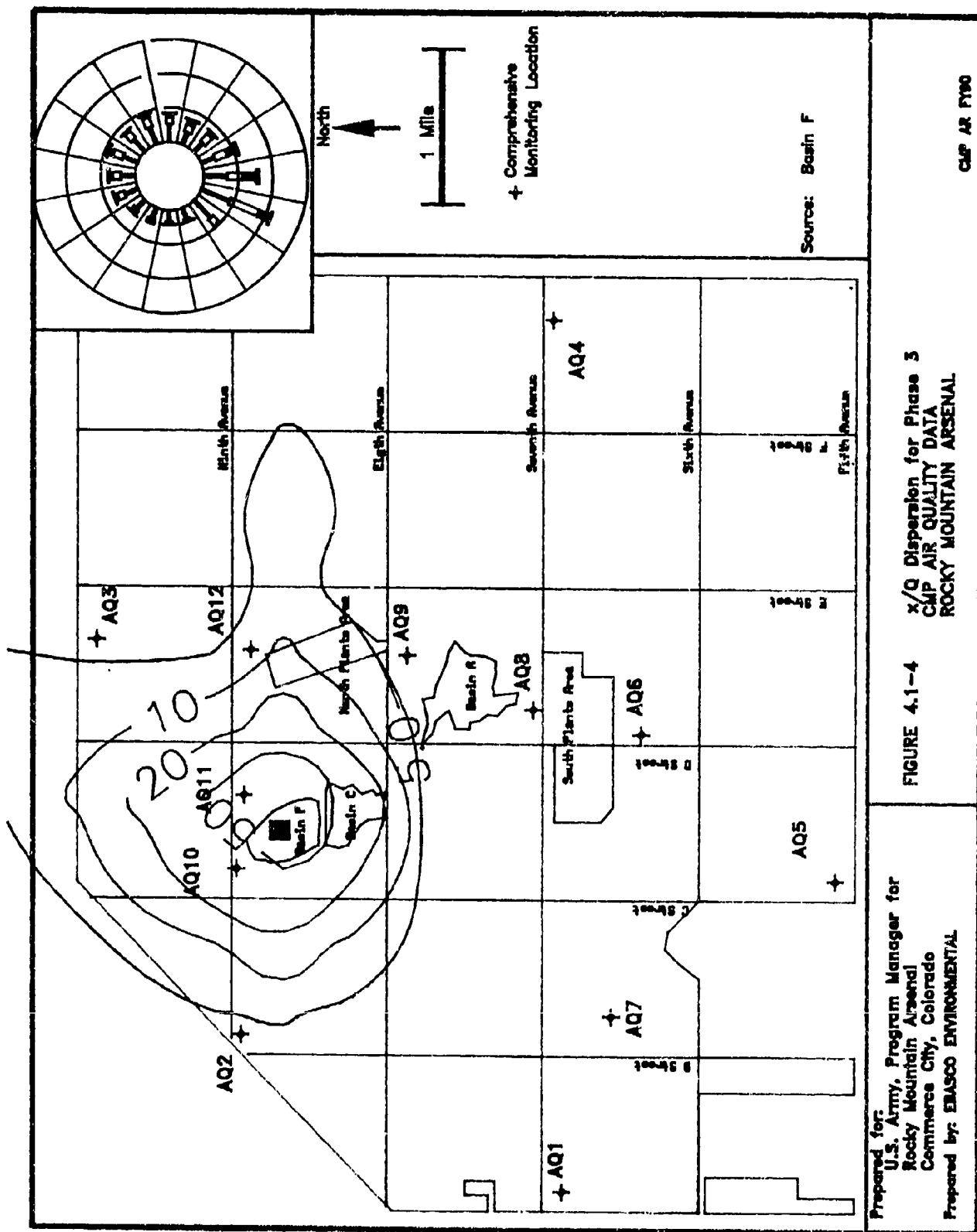
Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: EBASCO ENVIRONMENTAL

FIGURE 4.1-2

x/Q Dispersion for Phase 2 - Stage 1
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AIR F190





concentrations of potential Basin F source contaminants during remediation activities to be located adjacent to Basin F and just to the north of the Basin. Monitoring results for some compounds for FY88 and FY89 during remediation activity substantiated this premise.

The dispersion pattern is similar for the Phase 3 and Phase 4 periods, although there were seasonal variations. The dispersion patterns in fact, were closely identical for each phase of the remediation and post-remediation periods. The implication, therefore, is that any significant variations in monitoring results are most likely a function of source emissions rather than meteorological factors. As a brief example, high SVOC levels for several contaminants were noted during the Phase 1 period. During Phase 2, Phase 3 and Phase 4, these potential contaminant levels decreased significantly (under similar dispersion conditions), inferring that the potential Basin F emissions sources for these compounds were effectively contained at the conclusion of the Phase 1 period. Similar consequences for each of the monitored parameters will be discussed in following sections of this report.

4.1.4 SOURCE EMISSION FACTORS

One of the objectives of this air quality assessment is to identify those emission sources that contribute to ambient air levels measured by the RMA monitoring program. During the CMP FY88 period, it was established that Basin F was a potential source of several VOC, SVOC, and metals compounds associated with the remedial programs. Also, high TSP levels were evident at Basin F as a result of intense remedial construction activity. During the Phase 3 and Phase 4 post-remedial monitoring periods, data clearly demonstrated significant decreases in ambient levels for most of these compounds, reflecting decreased emissions from Basin F and the associated remedial program (see Section 4.2).

As Basin F emissions decrease, other potential RMA sources could come into focus, such as Basin A, the South Plants, the Hydrazine Plant, and localized construction activities (ie. Basin A Neck, the South Plants Subdrain activity). These sources, as of the FY90 data collection period, appear to be at lower levels of intensity, and in most cases their impacts, if any, are comparable to VOC, SVOC and metals levels measured in the urban environment of metropolitan Denver. In fact, it is difficult to evaluate CMP monitoring results for most pollutants measured during FY90 without examining the potential emission sources across the Denver urban area, and in particular, the external sources surrounding the Arsenal.

This problem was addressed to some extent in previous CMP Air Quality Data Assessment Reports (RLSA, 1990). For example, considerably higher TSP and metals levels frequently occurred at RMA perimeter sites AQ1 and AQ2 during 1989-90 winter inversion episodes. These conditions were generally attributed to metropolitan vehicle activity as well as other industrial activities that contribute to Denver "brown cloud" conditions. A number of mobile and stationary sources in metropolitan Denver may impact RMA air quality monitoring sites, depending upon temperature, wind direction, inversion conditions and other meteorological factors influencing the Denver area. This report further identifies these external conditions and sources. Table 4.1-2 and Figure 4.1-6 show selected sources in metropolitan Denver that may influence RMA air quality under relevant meteorological conditions. Several investigations relating levels of RMA-monitored gaseous pollutants as well as TSP, metals, VOC, and SVOC with off-Arsenal sources are provided in various sections of this report (Sections 4.2, 4.4, 4.6, 4.7 and 5.0). In addition, a study relating RMA gaseous monitoring data under various visibility conditions including Denver "brown cloud" episodes is provided in Section 6.0.

The following sections provide specific monitoring results and data evaluation for all parameters collected during the FY88 through FY90 programs; the data results of the Air Remedial Investigation Final Report (ESE, 1988) are also incorporated into the CMP database for long-term statistical assessment and the overall contamination assessment, as appropriate.

4.2 TOTAL SUSPENDED PARTICULATES (TSP)

4.2.1 CMP FY90 TSP RESULTS

Details of the FY90 sampling program for TSP at each of the monitoring locations are given in Table 4.2-1. Recoveries are based on the total number of planned days during the period after initiation. Samples were considered not valid if there were equipment malfunctions or the sample filter was damaged. According to PSD guidelines, a minimum of 23 hours of sampling was required for a valid sample.

TSP data are often reported by using the annual geometric mean values. This approach is based on early EPA guidance regarding standards, and is applied because the TSP monitoring data can be expected to fit a log-normal distribution. Under a log-normal distribution, there are a relatively large number of low concentrations and a small number of high concentrations. An arithmetic mean value

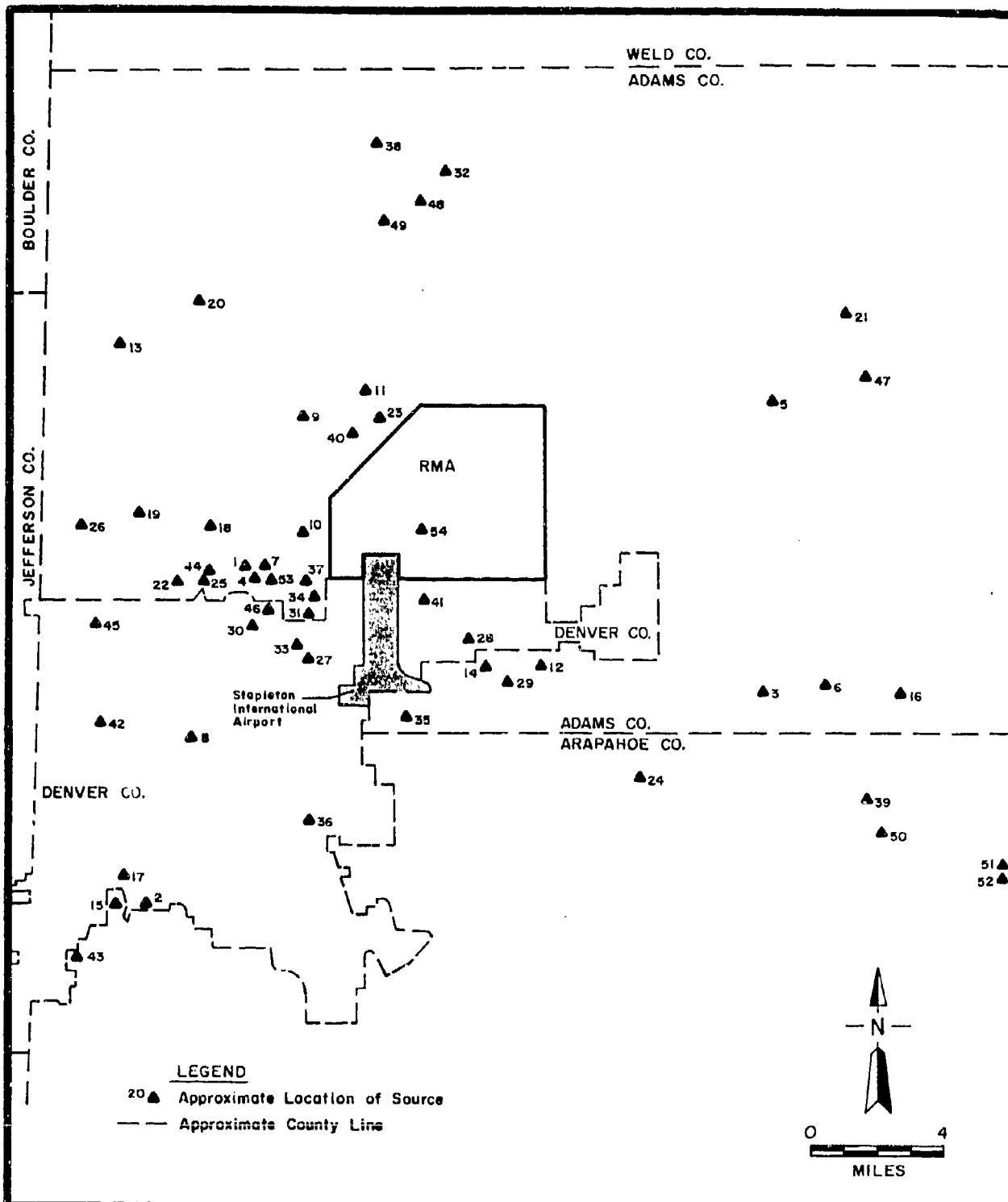
Table 4.1-2 Emissions Inventory Summary for Regulated Pollutants (in tons per year)

Facility	Map #	Part.	NO _x	SO ₂	VOC	CO
PSCO Cherokee Plant	1	213	14,731	11,753	56	500
PSCO Arapahoe Plant	2	21	3,098	1,511	10	90
Colo. Interstate Gas (Wat.)	3	4	718		29	162
Conoco Refining Inc.	4	116	567	2,182	3,632	240
Koch Hydrocarbon Co. (1)	5		454		15	84
Amoco Production Co. (Wat.)	6		407		9	51
Colorado Refining Co.	7	26	382	1,181	980	824
PSCO Zuni Plant	8		219			16
Wyco Pipeline	9				393	
Rainbo Bread Co.	10		2		194	
Sinclair Marketing	11				137	
Mastercraft (1)	12		2		125	7
AT&T Information Systems	13		27		105	
Chase Terminal	14				185	
Littleton/Englewood	15			262		
Amoco Production Co. (Byrs.)	16		373		9	48
Gates Rubber Co.	17	12	275	76	39	28
Metro Denver Sewage Disposal	18	3	130		29	145
Western Paving Co.	19	43	126	26	23	8
U.S. West	20	8	116	8	8	24
Amoco Production (3rd Ctr.)	21		107		3	14
Asarco Inc.	22	370	20			
Ralston Purina	23	3		51		3
U.S.A.F. Buckley Air Base	24	28	290	39	19	55
Diamond Shamrock Corp.	25				95	
Sunstrand Aviation Operation	26	22	2			
Pillow Kingdom Co. (Kearney)	27	4			99	
Samsonite Corp.	28	7	17			3
Whirlpool Kitchens Inc.	29					
Shafer Commercial Seating Co.	30				99	
Mesa Fiberglass Co.	31					
Alltac Corporation	32				80	
Pillow Kingdom Co. (2)	33				6	
W.J. Whatley Co.	34					
Stanley Aviation Corp.	35					

Table 4.1-2 Emissions Inventory Summary for Regulated Pollutants (continued)

Facility	Map #	Part.	NOX	SO2	VOC	CO
Redfield Rifle Co.	36	8			2	
Chemrex Inc.		37				
Vessel Gas Processing Co.	38		463	3	64	257
Gulf Energy Development	39		96		5	7
Oil & Solvent Processing Co.	40				59	
Scotts Liquid Gold Co.	41				47	
Advance Foam Plastics Inc.	42				96	
Verticel Co.	43				98	
Republic Paper Co.	44	4	27	54		4
Benjamin Moore Paint Co.	45	16			86	
Mastercraft (2)	46				99	
Koch Hydrocarbon Co. (AdmCty)	47		54	2	2	6
Brannan Sand & Gravel Co.	48	24		16	17	19
Zignan Sand & Gravel Co.	49	53				
Sun Gas Dragoon Compress.	50		124		4	14
Bijou Recycling	51				305	
Colo. Interstate Gas (Arap.)	52		211			27
Phillips Pipeline Co.	53				69	
Rocky Mountain Arsenal	54	1.2	25.2	5.4	1.9	7.3

Sources: Colorado Department of Health EISPS Inventory, May 1990.
 "Poisons in Our Neighborhoods." Citizens Fund, Appendices II & IX, June 1990.



Prepared for:

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.
Ebasco Services Inc.

Figure 4.1-6

Sources of Regulated Pollutants in
RMA Vicinity

Table 4.2-1 Summary of RMA Total Suspended Particulates (TSP) Monitoring for FY90

Station	No. Samples	% Recovery
AQ1	59	97
AQ2	58	95
AQ3	57	93
AQ4	59	97
AQ5	55	90
AQ5B	56	92
AQ6	59	97
AQ7	60	98
AQ8	60	98
AQ9	57	93
AQ10*	32	94
AQ10a	21	91
AQ10b	4	100
AQ11	58	95
AQ12	59	97
TOTAL:	754	95

- * The portable TSP monitor, AQ10, was moved from just north of Basin F to the northeast corner of Section 35 on April 20, 1990 (AQ10a). It was moved again on September 5, 1990, to the northwest quarter of Section 1 in the South Plants area (AQ10b) downwind of the Subdrain Remedial Activity.

would be greatly affected by the few very large values, while a geometric mean is much less affected by these extremes.

An arithmetic mean can be characterized as:

$$A = (a_1 + a_2 + a_3 + \dots + a_n)/n$$

While a geometric mean is the nth root of the product of the n observations:

$$G = (a_1 a_2 a_3 \dots a_n)^{1/n}$$

Where a_n is the nth observation (of TSP data);
n is the total number of valid observations;
A is the arithmetic mean of the sample; and
G is the geometric mean of the sample.

Monthly and annual TSP results for the FY90 Program for each monitoring station are summarized in Table 4.2-2 and Figure 4.2-1. Figure 4.1-5, previously shown, provides the X/Q dispersion pattern for the CMP FY90 monitoring period. Table 4.2-2 provides both annual arithmetic and geometric means as well as 24-hour maximum concentrations in standard volumes measured during the monitoring program. The arithmetic mean is provided for continuity purposes and for comparison with previous historical data (i.e., RI data). The 24-hour sequential data are provided in Appendix A.

The data indicate that annual arithmetic mean values ranged from a high of $64 \mu\text{g}/\text{m}^3$ at AQ10b, just to the north of the South Plants subdrain area, to a low of $33 \mu\text{g}/\text{m}^3$ at AQ4 on the eastern border of RMA. Annual geometric mean values ranged from a high of $52 \mu\text{g}/\text{m}^3$ to a low of $27 \mu\text{g}/\text{m}^3$. It is interesting that during FY88 and FY89, AQ10 and AQ11, both downwind of Basin F remedial activities, exceeded the annual standards. During FY90, both of these stations measured annual geometric means of $30 \mu\text{g}/\text{m}^3$, or 50 percent of the secondary standard of $60 \mu\text{g}/\text{m}^3$. Table 2.1-1 shows all ambient air quality standards, including TSP.

There were two exceedances of the 24-hour primary ambient air quality standard of $260 \mu\text{g}/\text{m}^3$ for TSP and 15 exceedances of the secondary 24-hour average ambient air quality standard of $150 \mu\text{g}/\text{m}^3$ during FY90. During FY89, there were 27 exceedances of the 24-hour TSP secondary standard; all of these exceedances occurred during the Basin F remediation period and almost all were at sites close to Basin F cleanup activities.

Table 4.2-2 Total Suspended Particulates (TSP) Sampling Results for CMP FY90 (in $\mu\text{g}/\text{m}^3$)

Month	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ10a	AQ10b	AQ11	AQ12
Summary of Geometric Mean Concentrations*															
October	66	86	42	43	48	43	44	50	42	38	49			46	42
November	57	75	37	33	39	38	34	37	31	30	38			33	31
December	35	63	22	22	35	34	25	26	26	26	25			25	21
January	40	46	28	25	39	37	24	27	27	24	29			24	21
February	49	55	28	21	36	36	27	33	28	25	32			28	25
March	17	21	12	10	15	14	11	13	11	13	12			11	10
April	24	30	24	20	20	19	22	21	21	19	36	34		19	19
May	35	40	29	26	28	29	62	30	29	26		30		30	28
June	43	70	49	43	47	48	113	44	49	43		46		46	47
July	31	41	42	25	27	27	36	30	30	25		30		29	29
August	48	70	51	42	43	46	58	47	47	38		45		44	41
September	50	57	46	39	42	43	49	46	45	37		36	44	46	39
ANNUAL	40	52	32	27	33	33	36	32	31	28	30	36	44	30	28
Summary of Arithmetic Mean Concentrations															
October	76	97	55	49	56	53	50	56	48	45	56			53	47
November	59	79	39	35	40	39	36	38	33	32	40			35	33
December	35	70	24	23	37	36	26	27	27	26	27			25	22
January	43	48	29	27	48	47	26	28	30	25	30			25	22
February	53	60	31	23	42	41	30	37	32	30	36			32	29
March	21	30	14	12	19	18	14	16	13	14	15			13	12
April	30	38	30	24	27	26	26	26	25	23	36	34		23	23
May	38	43	31	28	31	31	88	31	32	28		33		35	30
June	46	82	53	47	49	51	175	47	52	47		53		48	51
July	35	47	46	28	30	30	44	33	34	28		34		32	33
August	52	72	54	43	44	47	65	48	49	39		46		46	42
September	67	75	65	56	58	60	71	62	64	54		36	64	68	56
ANNUAL	47	63	39	33	40	40	55	38	37	34	35	41	64	37	34

Table 4.2-2 Total Suspended Particulates (TSP) Sampling Results for CMP FY90 (in $\mu\text{g}/\text{m}^3$) (continued)

Month	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ10a	AQ10b	AQ11	AQ12
Summary of 24-Hour Maximum Concentrations **															
October	133	161	98	73	96	93	84	91	84	76	100			97	82
November	80	107	57	54	56	53	52	54	50	49	58			53	46
December	45	116	45	34	53	51	34	36	34	29	46			29	26
January	72	73	47	39	124	122	45	46	50	37	42			39	31
February	85	102	67	46	86	85	64	76	68	67	70			70	63
March	46	76	28	22	38	36	25	31	24	20	32			28	21
April	52	65	48	31	43	42	38	43	40	37	41	34		39	37
May	59	66	51	49	53	56	247	53	64	51		59		57	51
June	67	127	83	67	63	67	396	62	77	85		92		75	75
July	55	73	77	42	43	44	74	51	49	47		57		48	54
August	86	104	77	61	67	66	133	72	78	58		68		67	60
September	184	208	194	171	170	181	212	180	188	164		36	169	214	167
ANNUAL	184	208	194	171	170	181	396	180	188	164	100	92	169	214	167

* Annual geometric mean standard is $75 \mu\text{g}/\text{m}^3$.

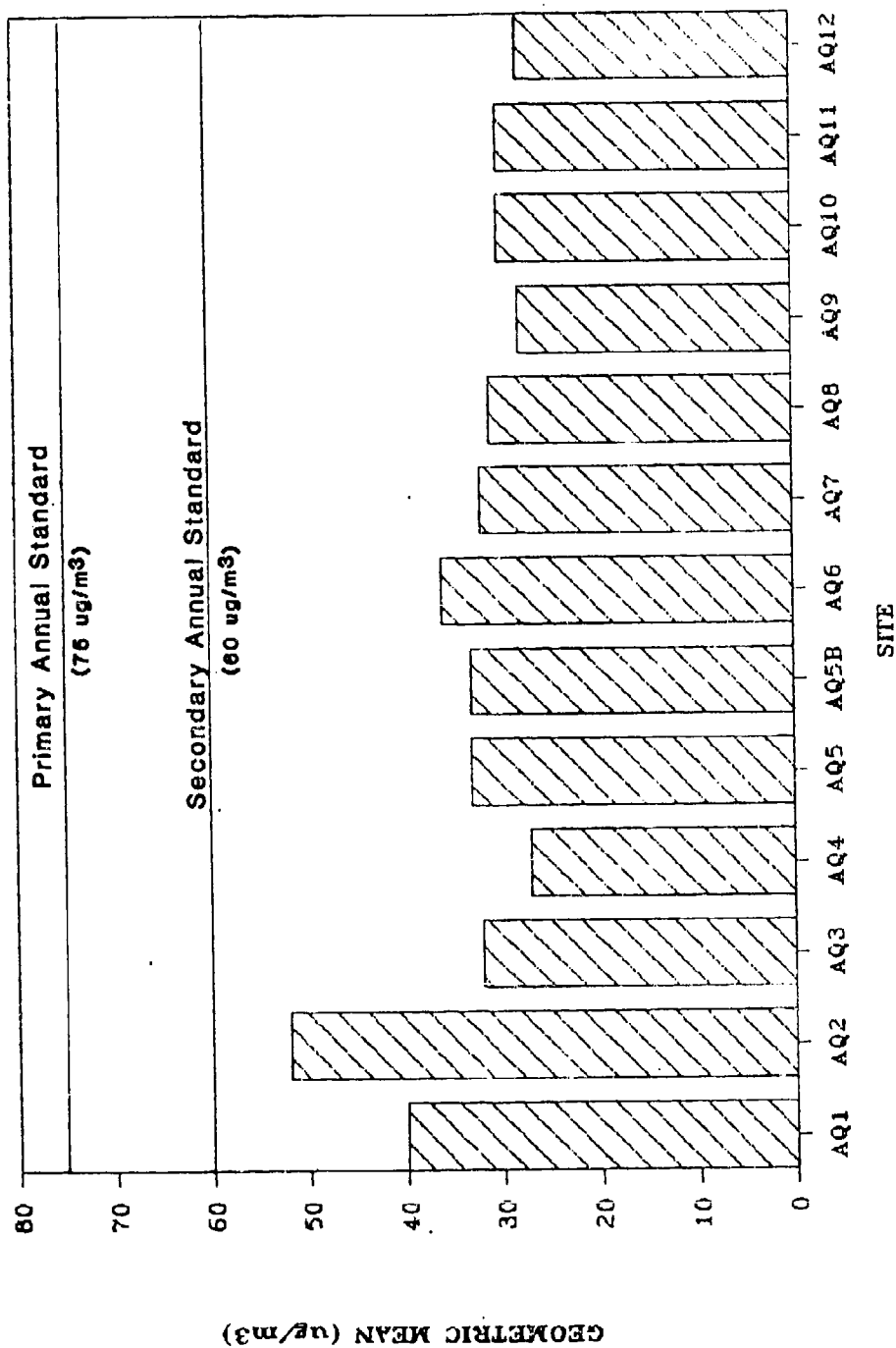
** Second-maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$. Primary maximum 24-hour standard is $260 \mu\text{g}/\text{m}^3$.

Note: FY90 is the period from October 1, 1989 to September 30, 1990.

AQ10 was located north of Basin F from October 1, 1989 through April 19, 1990.

AQ10a was located in the northeast corner of Section 35 from April 20 to September 4, 1990.

AQ10b was located in the northwest quarter of Section 1 from September 5, 1990 through the end of FY90.



Prepared for :
 U.S. Army Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by :
 R.L. Stollar & Associates, Inc.
 Ebasco Services, Inc.

Figure 4.2-1

CMP Total Suspended Particulates
 Results for FY90

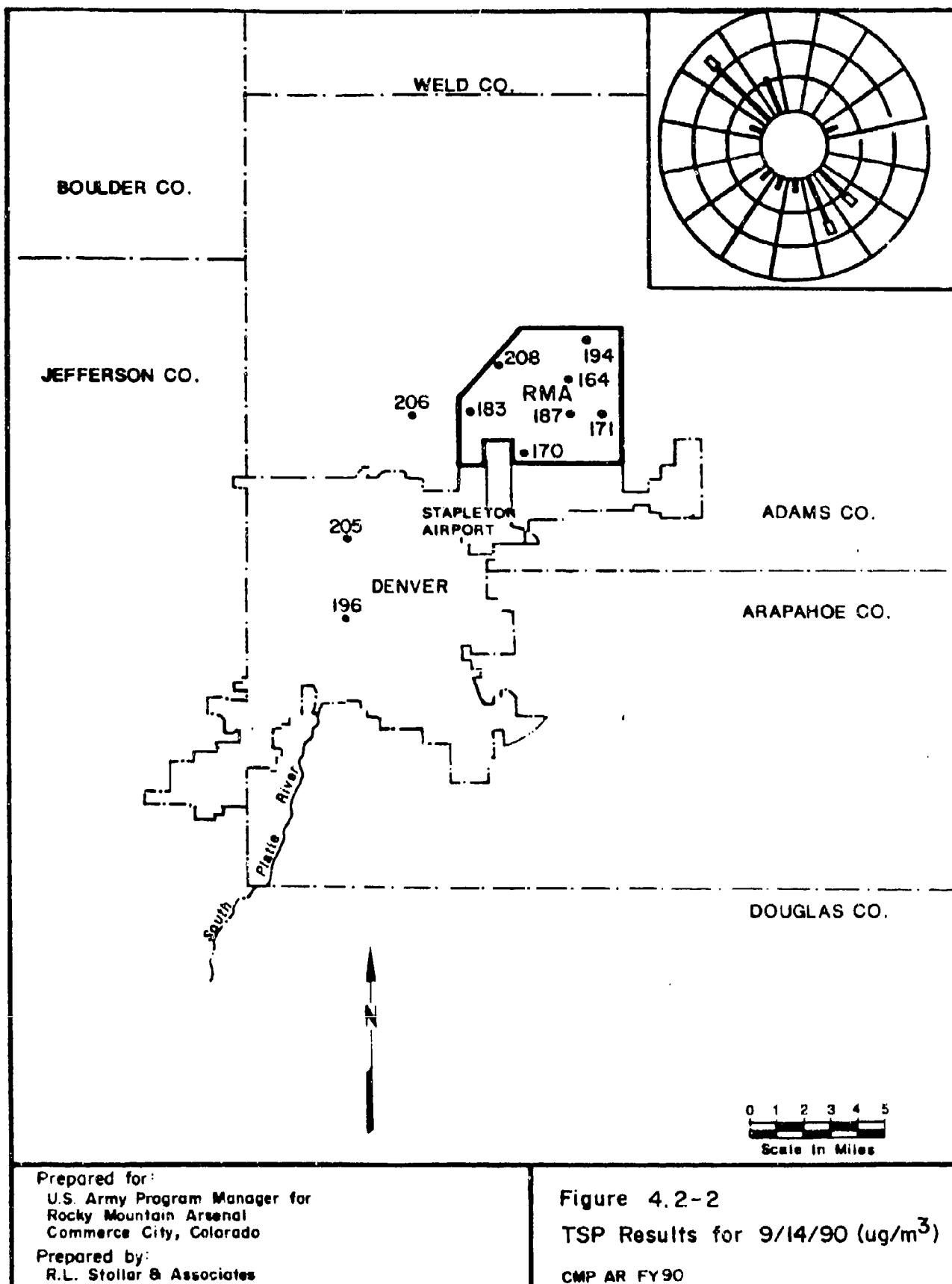
CMP AR FY90

During FY90, none of the TSP exceedances were attributed to dust from Basin F. Both of the 24-hour primary standard exceedances of 395 and 321 $\mu\text{g}/\text{m}^3$ occurred at AQ6, which was downwind of earthmoving and construction activity on the Lower Derby Lake spillway during June of 1990. This compares with numerous measurements of greater than 400 $\mu\text{g}/\text{m}^3$ during the Basin F remediation period.

All of the RMA monitoring sites exceeded the secondary air quality standard of 150 $\mu\text{g}/\text{m}^3$ on September 14, 1990 (almost all of the 24-hour secondary standard exceedances for the year occurred on this single day). Except at AQ2 and AQ6, this was the only violation of the 24-hour TSP standard, therefore, all other sites show compliance with the standard. (It is acceptable to exceed this value, 150 $\mu\text{g}/\text{m}^3$, once per year.) Figure 4.2-2 shows the distribution of TSP concentrations across the Arsenal and the Denver metropolitan area, along with the wind rose for the September 14 episode. The influx of pollutants onto the Arsenal can be attributed to synoptic meteorological influences, exacerbated by the proximity of the Arsenal to metropolitan Denver particulate sources. Downtown Denver reported TSP concentrations of greater than 200 $\mu\text{g}/\text{m}^3$ at the Camp location, while high TSP levels were reported across eastern Colorado as well.

The high pollution episode of September 14 was caused by an intense upper level inversion and light winds that strongly inhibited the dispersion of pollutants over a broad regional area. Frequently referred to as a "limited mixing" situation, this condition is illustrated in Figure 4.2-3, which is the 0600 MST September 14 upper air sounding (vertical profile of temperature, dew point and winds) from Stapleton Airport (Weatherbank, 1990). The shallow surface inversion is evident as well as the upper air inversion capping out at about 4,000 feet above the ground. Consequently, even after the elimination of the surface inversion with slight daytime warming, the upper level inversion confined pollutants to the lower boundary layer of the atmosphere until a new synoptic system moved across the area, or very significant daytime heating allowed the inversion to be "wiped out". The significance of this episode is that the worst pollution day of the FY90 monitoring period was caused by a unique meteorological phenomenon (i.e., limited mixing). Ambient concentrations not only of TSP, but of PM-10, metals and gaseous criteria pollutants across metropolitan Denver, as well as RMA, were influenced by the intensity of the event. Several case studies for other parameters on this date are discussed elsewhere in this report.

As another TSP example, Figure 4.2-4 shows the distribution of TSP across RMA on June 4, 1990. The maximum 24-hour TSP concentration observed at RMA during the year was 395.5 $\mu\text{g}/\text{m}^3$ measured at AQ6, close to the Lower Derby Lake spillway activity. The wind speed averaged greater



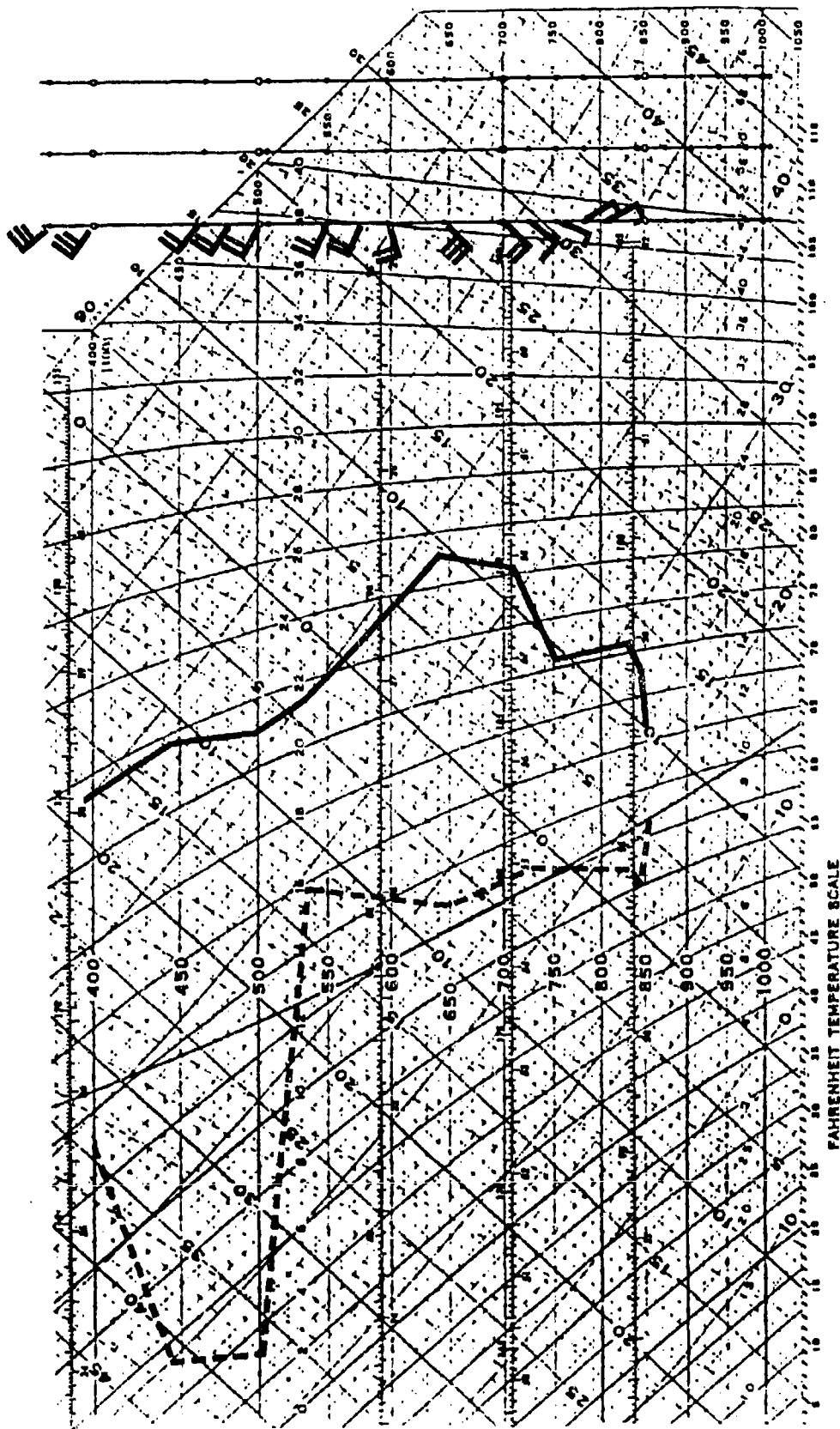


Figure 4.2-3
September 14, 1990 12Z Sounding
for Stapleton Airport

CMP AR FY 90

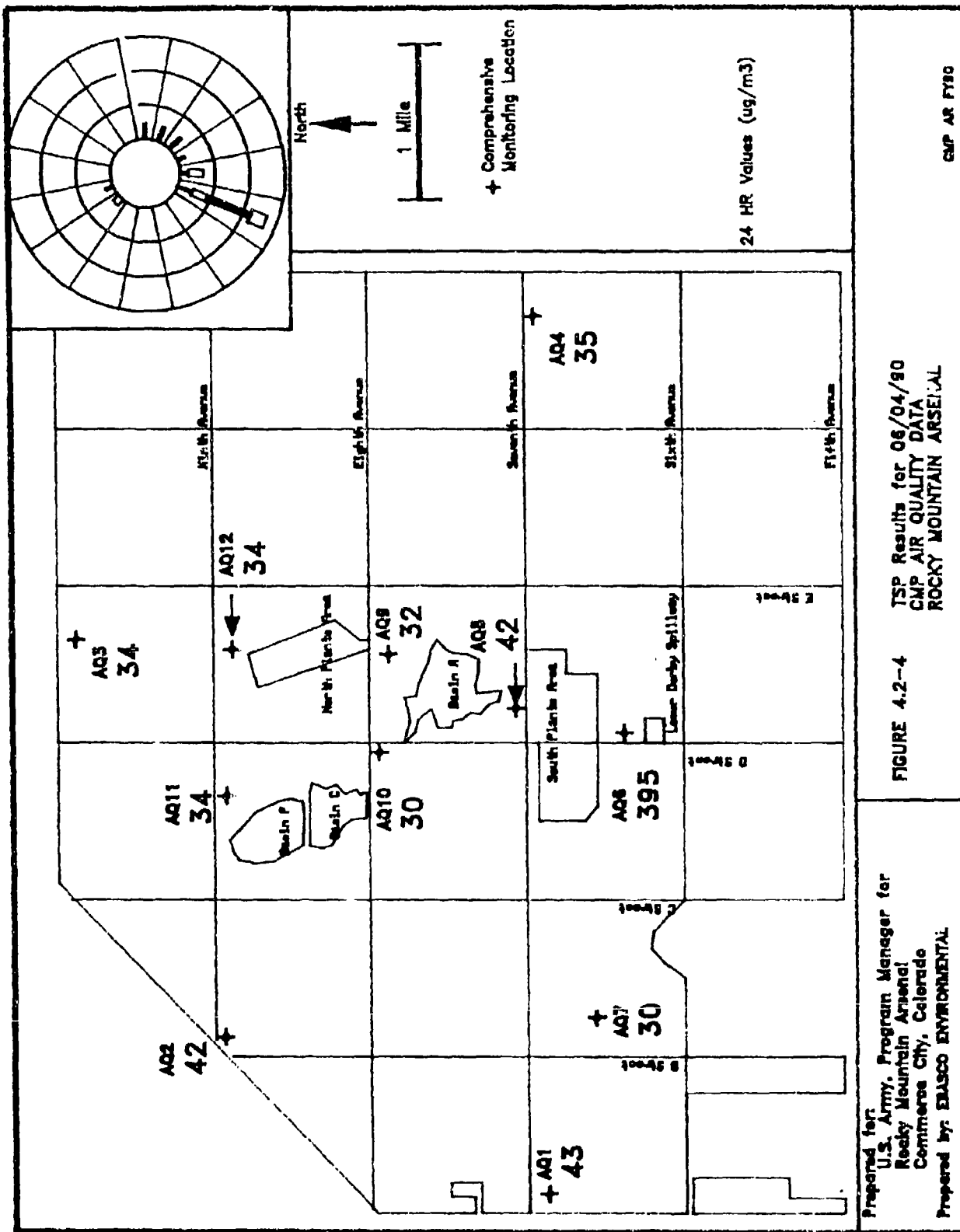
Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services Inc.

Legend

— Temperature

- - - Dewpoint Temperature

— Wind Speed and Direction



than 11 mph during the 24-hour period, which contributed to airborne dust from the construction activity. Nevertheless, all of the other 11 monitoring sites across the Arsenal (including AQ8 and AQ9, which were directly downwind of AQ6 on that day) measured TSP levels that were lower than AQ6 by a factor of 10, illustrating the localized nature of high TSP events associated with remedial activity.

4.2.2 ASSESSMENT OF BASIN F TSP POST-REMEDIAL IMPACTS

4.2.2.1 CMP TSP Monitoring Results

Because of the varying source impacts from Basin F during the remedial and post-remedial monitoring periods, results and comparisons with all monitored data were considered with respect to the different phases and stages of the cleanup operations. Table 4.2-3 provides a description of annual geometric mean, average and 24-hour maximum TSP monitoring results by month from the start of CMP FY88 to the conclusion of CMP FY90. At the bottom of the monthly data is a summary of the concentrations for each phase of the monitoring period. Also, in order to establish pre-remedial baseline values, results of the 1986-1987 IR Program are provided (ESE, 1988) (only average and maximum values are shown for these data as geometric means were not calculated). Phase 1 shows results of CMP FY88 and FY89 data which were concurrent with remediation activity; Phase 2 (Stage 1) shows results of the FY89 program after the initial cap was placed on Basin F, but extensive ground moving activities were in progress; Phase 2 (Stage 2) shows results during the final Basin F remedial and landscaping activity. Phase 3 provides post-remedial TSP monitoring data during the last 5 months of the CMP FY89, and Phase 4 provides post-remedial TSP monitoring data during the 12 months of CMP FY90.

It is clear from these data that Basin F remedial activity had an impact on those CMP stations that were located immediately adjacent to or downwind from Basin F, especially AQ10, 11, and 12. The highest monthly average and maximum 24-hour concentrations occurred in the latter months of Phase 1 and in Phase 2, Stage 1, when earth moving activities were most intense. A maximum 24-hour TSP value of $738 \mu\text{g}/\text{m}^3$ was measured at AQ11 on January 22, 1989. At all stations, TSP levels decreased to pre-remedial baseline values during the post-remediation periods (Phase 3 and Phase 4). Figure 4.2-5 also provides a graphical depiction of this progression for arithmetic means and 24-hour maximum values at AQ10, the CMP mobile station immediately downwind and north of Basin F. The transitory impacts of remediation activity are clearly defined in these data. TSP levels reached their peak during the intense remediation of Phase 1, then decreased to pre-remedial levels during the

Table 4.2-3 Total Suspended Particulates (TSP) Sampling Results for CMP Phases 1-4 (in $\mu\text{g}/\text{m}^3$)

Summary of Geometric Mean Concentrations *															
Month	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ10a	AQ10b	AQ11	AQ12
PHASE 1															
March	70	93	37		55	60	45	58	59	93				70	44
April	43	60	33		38	36	35	40	40	35				38	31
May	34	41	29		29	28	26	30	30	25				43	26
June	38	61	38		37	36	35	39	39	36				95	77
July	54	74	45		46	46	42	45	48	45				89	67
August	58	80	54	50	45	45	43	49	50	47	62			68	93
September	44	72	37	31	29	30	27	31	36	35	86			81	61
October	54	83	53	49	41	42	38	48	43	42	109			169	101
November	56	63	33	32	38	40	32	36	32	32	62			66	42
December	82	87	51	43	55	55	45	50	52	52	104			84	44
PHASE 2 - STAGE 1															
December	60	57	37	30	41	42	36	41	35	32	76			91	32
January	57	67	34	26	51	45	29	35	38	26	74			143	59
February	58	143	40	39	52	47	41	41	44	42	54			239	57
PHASE 2 - STAGE 2															
February	29	37	13	12	25	23	17	19	16	16	24			76	13
March	56	73	34	33	50	47	37	40	36	37	62			119	97
April	41	56	26	31	33	30	27	26	25	26	39			48	29
May	48	71	30			30	31	32	78	25	57			43	28
PHASE 3															
May	44	41	34	32	38	37	33	37	34	33	35			36	34
June	34	37	27	31	28	29	27	30	28	25	34			28	27
July	57	84	49	48	46	47	48	50	62	44	61			54	53
August	35	51	33	30	31	31	32	32	32	29	41			36	34
September	48	61	49	44	40	41	50	53	41	34	39			35	34

Table 4.2-3 Total Suspended Particulates (TSP) Sampling Results for CMP Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of Geometric Mean Concentrations *															
Month	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ10a	AQ10b	AQ11	AQ12
PHASE 4															
October	66	86	42	43	48	43	44	50	42	38	49			46	42
November	57	75	37	33	39	38	34	37	31	30	38			33	31
December	33	63	22	22	35	34	25	26	26	26	25			25	21
January	40	46	28	25	39	37	24	27	27	24	29			24	21
February	49	55	28	21	36	36	27	33	28	25	32			28	25
March	17	21	12	10	15	14	11	13	11	13	12			11	10
April	24	30	24	20	20	19	22	21	21	19	36	34		19	19
May	35	40	29	26	28	29	62	30	29	26		30		30	28
June	43	70	49	43	47	48	113	44	49	43		46		46	47
July	31	41	42	25	27	27	36	30	30	25		30		29	29
August	48	70	51	42	43	46	58	47	47	38		45		44	41
September	50	57	46	39	42	43	49	46	45	37		36	44	45	39
Phase 1	50	68	40	40	39	39	35	40	40	38	81			74	55
Phase 2-1	58	76	37	30	48	45	33	38	39	31	68			145	49
Phase 2-2	44	58	26	27	37	34	29	30	29	28	44			72	41
Phase 3	42	52	37	37	36	36	36	38	38	32	41			37	36
Phase 4	40	52	32	27	33	33	36	32	31	28	30	36	44	30	28

* Annual primary geometric mean standard is $75 \mu\text{g}/\text{m}^3$.

Table 4.2-3 Total Suspended Particulates (TSP) Sampling Results for CMP Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of Arithmetic Mean Concentrations															
Month	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ10a	AQ10b	AQ11	AQ12
PHASE 1															
March	71	94	55		59	62	50	61	63	93				83	47
April	50	65	41		45	43	43	46	46	43				49	37
May	36	43	31		31	29	27	32	31	27				55	28
June	42	65	42		40	38	37	41	42	39				101	102
July	57	76	48		48	48	43	47	49	47				95	70
August	66	97	60	58	50	50	47	55	55	52	69			76	163
September	56	88	51	42	39	39	36	41	42	36	120			157	93
October	56	87	56	50	43	44	39	49	44	43	112			228	108
November	57	66	34	33	39	41	32	38	34	33	66			66	44
December	92	104	61	51	59	59	50	54	56	59	159			118	49
PHASE 2 - STAGE 1															
December	64	57	40	32	47	48	40	46	39	34	86			107	35
January	68	76	37	30	58	54	36	41	42	32	92			231	118
February	90	150	57	53	85	79	67	70	64	63	73			292	66
PHASE 2 - STAGE 2															
February	32	38	15	13	29	27	18	22	18	18	24			94	14
March	61	80	37	37	54	50	39	42	38	40	69			151	156
April	45	59	30	32	37	34	30	30	29	28	43			54	33
May	48	71	30			30	31	32	78	25	57			43	28
PHASE 3															
May	44	43	34	34	38	38	34	37	35	34	36			38	35
June	40	50	35	39	36	36	34	36	36	33	41			35	34
July	59	92	52	51	49	50	51	53	65	47	65			57	57
August	35	51	33	32	32	32	33	33	33	29	42			36	35
September	52	70	52	52	43	43	51	54	46	37	45			39	39

Table 4.2-3 Total Suspended Particulates (TSP) Sampling Results for CMP Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of Arithmetic Mean Concentrations															
Month	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ10a	AQ10b	AQ11	AQ12
PHASE 4															
October	76	97	55	49	56	53	50	56	48	45	56			53	47
November	59	79	39	35	40	39	36	38	33	32	40			35	33
December	55	70	24	23	37	36	26	27	27	26	27			25	22
January	43	48	29	27	48	47	26	28	30	25	30			25	22
February	53	60	31	23	42	41	30	37	32	30	36			32	29
March	21	30	14	12	19	18	14	16	13	14	15			13	12
April	30	38	30	24	27	26	26	26	25	23	36	34		23	23
May	38	43	31	28	31	31	88	31	32	28		33		35	30
June	46	82	53	47	49	51	175	47	52	47		53		48	51
July	35	47	46	28	30	30	44	33	34	28		34		32	33
August	52	72	54	43	44	47	65	48	49	39		46		46	42
September	67	75	65	56	58	60	71	62	64	54		36	64	68	56
Pre-Rem	55	52	35	42	42		38	39	38	36	44			38	35
Phase 1	56	77	47	47	43	43	39	45	44	43	99			103	79
Phase 2-1	73	88	44	37	62	59	45	50	47	41	84			214	81
Phase 2-2	49	64	30	31	42	39	32	34	34	31	51			96	77
Phase 3	46	61	41	42	40	40	40	42	43	36	46			41	40
Phase 4	47	63	39	33	40	40	55	38	37	34	35	41	64	37	34

Table 4.2-3 Total Suspended Particulates (TSP) Sampling Results for CMP Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of 24-Hour Maximum Concentrations *															
Month	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ10a	AQ10b	AQ11	AQ12
PHASE 1															
March	79	111	95		83	78	70	80	86	93				126	64
April	88	118	87		87	83	86	86	87	86				101	81
May	53	63	43		47	45	36	50	43	38				118	45
June	67	96	73		64	62	61	63	75	67				166	238
July	82	100	74		64	65	56	65	59	62				152	111
August	105	196	96	120	82	81	78	91	87	89	108			115	590
September	94	138	94	84	71	69	63	75	72	46	252			389	190
October	81	129	76	72	69	73	54	66	61	57	158			542	165
November	69	82	46	37	51	53	42	54	48	46	115			72	71
December	134	162	93	79	82	83	71	73	76	85	279			201	72
PHASE 2 - STAGE 1															
December	87	60	64	45	76	78	62	65	62	52	141			189	52
January	131	149	68	63	117	113	79	88	79	65	175			738	425
February	179	198	113	102	183	172	143	156	130	127	146			561	116
PHASE 2 - STAGE 2															
February	47	47	21	17	43	40	26	32	26	25	29			148	20
March	86	115	53	58	75	68	57	59	55	65	122			294	467
April	64	84	51	43	53	46	54	49	50	41	71			93	49
May	48	71	30			30	31	32	78	25	57			43	28
PHASE 3															
May	52	51	41	45	44	45	42	45	43	40	45			56	43
June	75	117	82	82	79	78	76	77	84	76	13			76	80
July	82	124	80	74	72	73	76	78	78	68	90			84	86
August	48	68	42	52	44	44	43	41	47	38	49			43	48
September	82	130	82	92	63	64	64	63	70	59	75			66	65
PHASE 4															
October	133	161	98	73	95	93	84	91	84	76	100			97	82
November	80	107	57	54	56	53	52	54	50	49	58			53	46

AIR-TBL2.90

Table 4.2-3 Total Suspended Particulates (TSP) Sampling Results for CMP Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of 24-Hour Maximum Concentrations *															
Month	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ10a	AQ10b	AQ11	AQ12
PHASE 4 (continued)															
December	45	116	45	34	53	51	34	36	34	29	46			29	26
January	72	73	47	39	124	122	45	46	50	37	42			39	31
February	85	102	67	46	86	85	64	76	58	67	70			70	63
March	46	76	28	22	38	36	25	31	24	20	32			28	21
April	52	65	48	31	43	42	38	43	40	37	41	34		39	37
May	59	66	51	49	53	56	247	53	64	51		59		57	51
June	67	127	83	67	63	67	396	62	77	85		92		75	75
July	55	73	77	42	43	44	74	51	49	47		57		48	54
August	86	104	77	61	67	66	133	72	78	58		68		67	60
September	184	208	194	171	170	181	212	180	188	164		36	169	214	167
Pre-Rem	143	112	80	47	109		151	101	95	82	71			91	77
Phase 1	134	196	96	120	87	83	86	91	87	93	279			542	590
Phase 2-1	179	198	113	102	183	172	143	156	130	127	175			738	425
Phase 2-2	86	115	53	58	75	68	57	59	78	65	122			294	467
Phase 3	82	130	82	92	79	78	76	78	84	76	90			84	86
Phase 4	184	208	194	171	170	181	396	180	188	164	100	92	169	214	167

* Second-maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$. Primary maximum 24-hour standard is $260 \mu\text{g}/\text{m}^3$.

Note: Pre-Rem refers to data collected during the Air Remedial Investigation, June 1986 to June 1987 (Environmental Science & Engineering, Inc., 1988), where only arithmetic mean and maximum data were available.

Phase 1 is from March 22 to December 12, 1988.

Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.

Phase 2, Stage 2 is from February 15 to May 5, 1989.

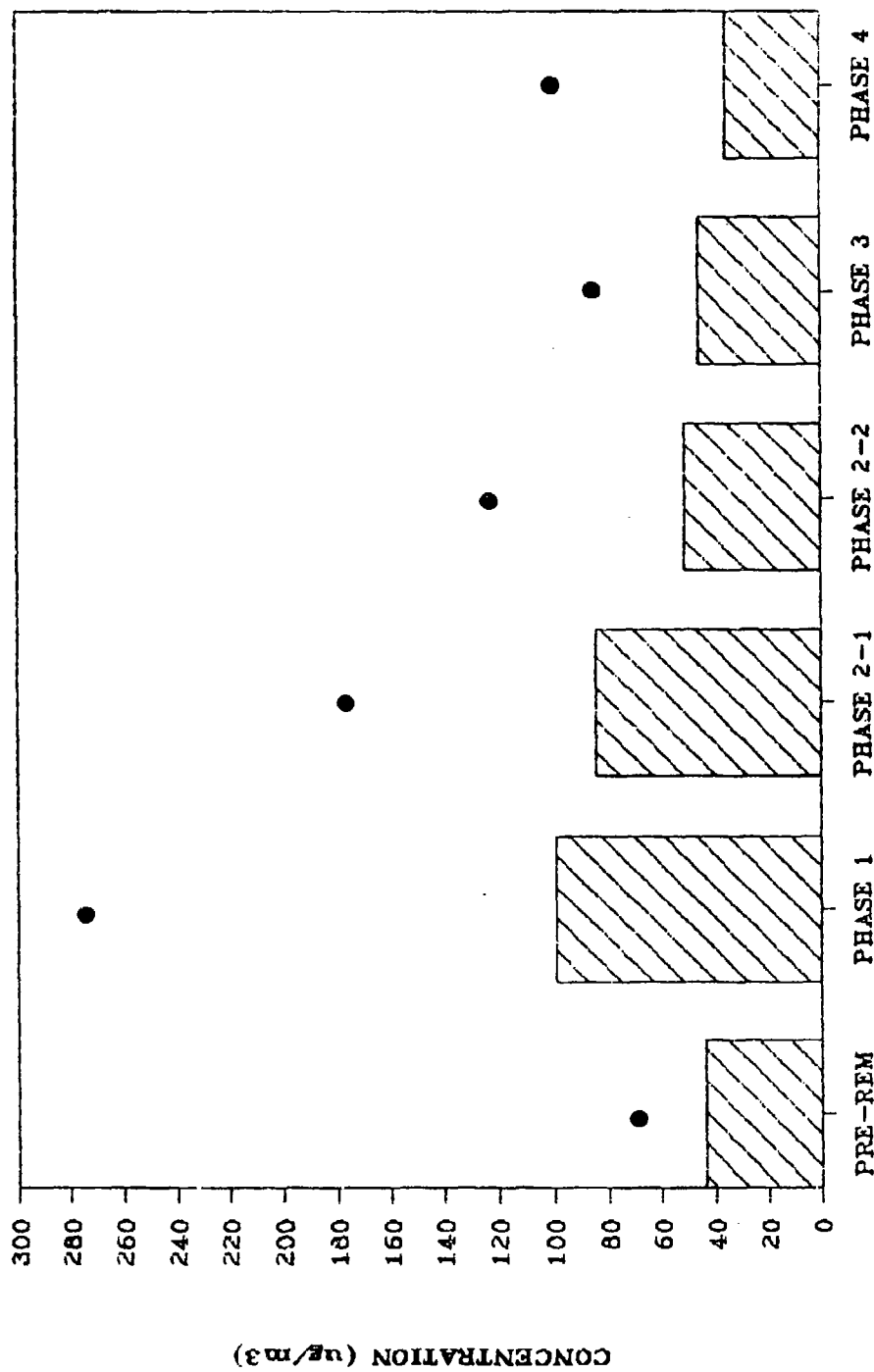
Phase 3 is from May 6 to September 30, 1989.

Phase 4 is from October 1, 1989 to September 30, 1990 (FY90).

AQ10 was located north of Basin F from October 1, 1989 through April 19, 1990.

AQ10a was located in the northeast corner of Section 35 from April 20 to September 4, 1990.

AQ10b was located in the northwest quarter of Section 1 from September 5, 1990 through the end of FY90.



ARITHMETIC MEAN

MAXIMUM

Phase 4 Data are from AQ10 at the Basin F location.

Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 4.2-5
TSP Concentrations at AQ10
During Remediation Phases
CMP AR FY90

post-remediation period. While maximum 24-hour values may have varied extensively on a day-to-day basis, the same general trend as the average values is evident.

The RMA TSP interior and boundary monitoring stations at farther distances from Basin F showed minimal impacts from the remediation activity, and other variations that were mostly attributed to seasonal and meteorological conditions. This is particularly true of AQ1 and AQ2 which were located at the western and northwestern boundaries of RMA, thereby receiving the greatest impacts from metropolitan Denver. The highest levels at these stations were measured during the winter period of January and February, 1989, coincident with days when downtown Denver experienced very high TSP values. These were periods of intense inversions and the movement of potential "brown cloud" conditions from downtown Denver in the direction of the Arsenal. This will be discussed subsequently and individual cases will also illustrate these phenomena.

The results of the CMP data reflecting TSP Basin F remedial impacts are further substantiated by data collected under the Basin F Interim Remediation Monitoring Program and the follow-on IRA-F monitoring program discussed in the next section.

4.2.2.2 Basin F TSP Monitoring Results

During FY88, FY89, and FY90, the CMP air monitoring network at RMA was supplemented and augmented by two major monitoring programs associated with Basin F cleanup activities. These were the Basin F Interim Remediation Air Monitoring Program and the follow-on IRA-F Air Monitoring Program. These programs ran continuously from May 1988 through September 1990. The network of stations and parameter monitors is discussed in Sections 3.3 and 3.4.

Annual geometric mean, arithmetic mean and 24-hour maximum TSP concentrations collected under the special Basin F monitoring programs, by month and phase are shown in Table 4.2-4. Data from Phases 1 and 2 comprise the Basin F Interim Remediation Monitoring Program, while Phases 3 and 4 comprise data from the IRA-F post-remedial program. Detailed daily results from the IRA-F Phase 4 period are also provided in Appendix L.

The Basin F network was designed specifically to evaluate impacts surrounding the remedial activity during and after cleanup operations. The progress of impacts is illustrated graphically in Figure 4.2-6 which shows TSP levels during each phase of the program at seven monitoring stations. In all cases concentration levels dropped significantly during the Phase 3 and Phase 4 post-remedial periods.

Table 4.2-4 Total Suspended Particulates (TSP) Sampling Results for Basin F/IRA-F/RIFS Phases 1-4 (in $\mu\text{g}/\text{m}^3$)

Summary of Geometric Mean Concentrations *											
Month	BF1/FC1	BF2/FC2	BF2C/FC2D	BF3/FC3	BF4/FC4	BF5	FC5	BF6	BF7	RIFS1	RIFS1D RIFS2
PHASE 1											
May	121	45	63		84	88		80	43		
June	75	81	112		130	59		100	47		
July	113	144	177	114	143	74		102	60		
August	82	88	75	60	83	67		56	49		
September	173	171	263	51	119	51		201	38		
October	163	185	192	99	166	75		126	63		
November	251	132	75	49	92	34		43	29		
December	149	210	180	61	138	73		58	44		
PHASE 2 - STAGE 1											
December	88	213	625	63	73	55		74	40	81	74
January	66	90	142	40	62	42		69	36	60	65
February	100	114	75	97	112	86		102	76	85	108
PHASE 2 - STAGE 2											
February	58	82	134	53	63	50		235	44	35	48
March	65	111	120	62	78	38		128	35	58	45
April	64	65	98	53	95	58		87	60	67	86
May	46	36	46	38	104	47		44	44	59	
PHASE 3											
May	45	43	44	42	46	41			40	51	
June		25	27	34	27	26			27	27	
July		54	59	59	62			46			
August	45	42	42	48	42			64			
September	59	45	46	44	46			59			

Table 4.2-4 Total Suspended Particulates (TSP) Sampling Results for Basin F/IRA-F/RIFS Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of Geometric Mean Concentrations *											
Month	BF1/FC1	BF2/FC2	BF2C/FC2D	BF3/FC3	BF4/FC4	BF5	FC5	BF6	BF7	RIFS1	RIFS1D RIFS2
PHASE 4											
October	79	77	78	70	68		82				
November	47	37	38	40	36		45				
December	27	24	26	26	27		26				
January	34	29	26	27	27		37				
February	34	27	27	19	24		28				
March	9	9	10	8	10		10				
April	33	31	33	31	32		39				
May	22	26	27	18	27		29				
June	49	51	53	36	47		59				
July	45	40	38	37	40		53				
August	64	70	74	51	62		76				
September	75	65	64	62	57		92				
Phase 1	105	122	135	68	117	64		89	47	68	75 46
Phase 2-1	78	119	190	53	72	48		76	44		40
Phase 2-2	62	81	104	55	80	45		109	43	56	
Phase 3	49	39	40	44	42	31	54		32	35	
Phase 4	39	36	37	32	35		44				

* Annual geometric mean standard is $75 \mu\text{g}/\text{m}^3$.

Table 4.2-4 Total Suspended Particulates (TSP) Sampling Results for Basin F/IRA-F/RIFS Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of Arithmetic Mean Concentrations *										
Month	BF1/FC1	BF2/FC2	BF2C/FC2D	BF3/FC3	BF4/FC4	BF5	FC5	BF6	BF7	RIFS1 RIFS2 RIFS3 RIFS4 RIFS5
PHASE 1										
May	122	48	63		95	95		102	50	
June	84	96	140		143	63		102	49	
July	119	190	190	116	144	75		105	61	
August	87	106	103	69	96	93		61	55	
September	221	252	331	79	158	59		249	43	
October	175	204	202	114	174	76		142	64	
November	121	235	121	52	112	37		49	31	
December	106	238	204	65	169	91		60	47	
PHASE 2 - STAGE 1										
December	95	327	626	69	74	61		130	54	82 75 55
January	94	112	162	42	69	50		80	38	67 65 44
February	105	118	75	102	116	87		102	77	102 112 67
PHASE 2 - STAGE 2										
February	65	88	134	56	70	50		235	44	48 48 31
March	69	162	166	67	83	39		187	36	62 47 65
April	70	72	99	59	108	58		87	61	70 89
May	47	37	46	39	104	47		44	44	59
PHASE 3										
May	45	43	44	42	46	41			41	51
June		28	30	36	31	30	46		30	32
July		61	67	65	70		67			
August	46	42	43	48	43		60			
September	69	48	50	49	50		54			

Table 4.2-4 Total Suspended Particulates (TSP) Sampling Results for Basin F/IRA-F/RIFS Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of Arithmetic Mean Concentrations *											
Month	BF1/FC1	BF2/FC2	BF2C/FC2D	BF3/FC3	BF4/FC4	BF5	FC5	BF6	BF7	RIFS1	RIFS2
PHASE 4											
October	83	82	84	73	70		89				
November	48	38	39	41	37		48				
December	27	24	26	26	27		26				
January	35	29	27	28	27		37				
February	35	27	27	20	24		28				
March	10	11	11	9	11		11				
April	34	32	33	31	33		39				
May	22	28	30	18	29		31				
June	53	51	53	37	49		60				
July	46	41	40	38	41		56				
August	65	70	74	54	66		77				
September	105	97	97	83	82		184				
Phase 1	123	173	178	83	137	74		112	51	76	52
Phase 2-1	96	173	267	60	79	56		96	50	77	52
Phase 2-2	66	110	134	60	88	47		147	45	64	48
Phase 3	53	43	45	47	46	35	57		34	39	
Phase 4	49	46	47	40	43		62				

* Annual geometric mean standard is $75 \mu\text{g}/\text{m}^3$.

Table 4.2-4 Total Suspended Particulates (TSP) Sampling Results for Basin F/IRA-F/RIFS Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of 24-Hour Maximum Concentrations *										
Month	BF1/FC1	BF2/FC2	BF2C/FC2D	BF3/FC3	BF4/FC4	BF5	FC5	BF6	BF7	RIFS1 RIFS1D RIFS2
PHASE 1										
May	128	66	63		158	128		202	88	
June	163	240	318		295	104		129	76	
July	164	370	296	151	167	82		141	71	
August	165	277	235	175	175	260		100	94	
September	399	591	622	274	324	120		430	75	
October	315	309	305	286	233	95		283	81	
November	251	902	282	96	204	46		82	46	
December	149	367	354	98	280	167		70	70	
PHASE 2 - STAGE 1										
December	161	687	659	111	94	85		236	89	95 81
January	276	285	255	59	132	120		171	52	77 72
February	154	147	75	143	162	95		105	86	143 121
PHASE 2 - STAGE 2										
February	107	115	134	83	116	50		235	44	48 43
March	104	514	471	106	130	55		493	52	59 77
April	104	103	107	107	160	71		91	76	111 109
May	47	41	46	46	104	47		44	44	59
PHASE 3										
May	47	50	50	48	51	46			45	52
June		38	39	50	40	44	46		39	42
July		89	96	94	103		87			
August	48	44	45	51	47		68			
September	105	67	70	69	40		76			

Table 4.2-4 Total Suspended Particulates (TSP) Sampling Results for Basin F/IRA-F/RIFS Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Summary of 24-Hour Maximum Concentrations *										
Month	BF1/FC1	BF2/FC2	BF2C/FC2D	BF3/FC3	BF4/FC4	BF5	FC5	BF6	BF7	RIFS1 RIFS1D RIFS2
PHASE 4										
October	114	117	122	89	92		135			
November	57	48	50	49	50		71			
December	27	25	26	27	28		26			
January	42	37	37	37	31		43			
February	41	28	27	26	27		31			
March	14	15	15	12	16		15			
April	40	38	39	38	39		39			
May	25	46	50	21	46		39			
June	72	58	59	53	62		67			
July	56	49	48	46	51		80			
August	78	72	75	70	87		85			
September	227	220	220	173	181		471			
Phase 1	399	902	622	286	324	260		430	94	
Phase 2-1	276	687	659	143	162	120		236	89	121
Phase 2-2	107	514	471	107	160	71		493	76	77
Phase 3	105	89	96	94	103	46			45	
Phase 4	227	220	220	173	181					

* Second-maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$.

Note: Phase 1 is from March 22 to December 12, 1988.

Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.

Phase 2, Stage 2 is from February 16 to May 5, 1989.

Phase 3 is from May 5 to September 30, 1989.

Phase 4 is from October 1, 1989 to September 30, 1990.

The Basin F sites were redesignated as "FC" sites upon commencement of the IRA-F program. Sites BF3 and BF4 remained in operation until June 1989, when they were moved slightly within the same area and designated as "FC" sites under the IRA-F program.

TSP Results By Phase

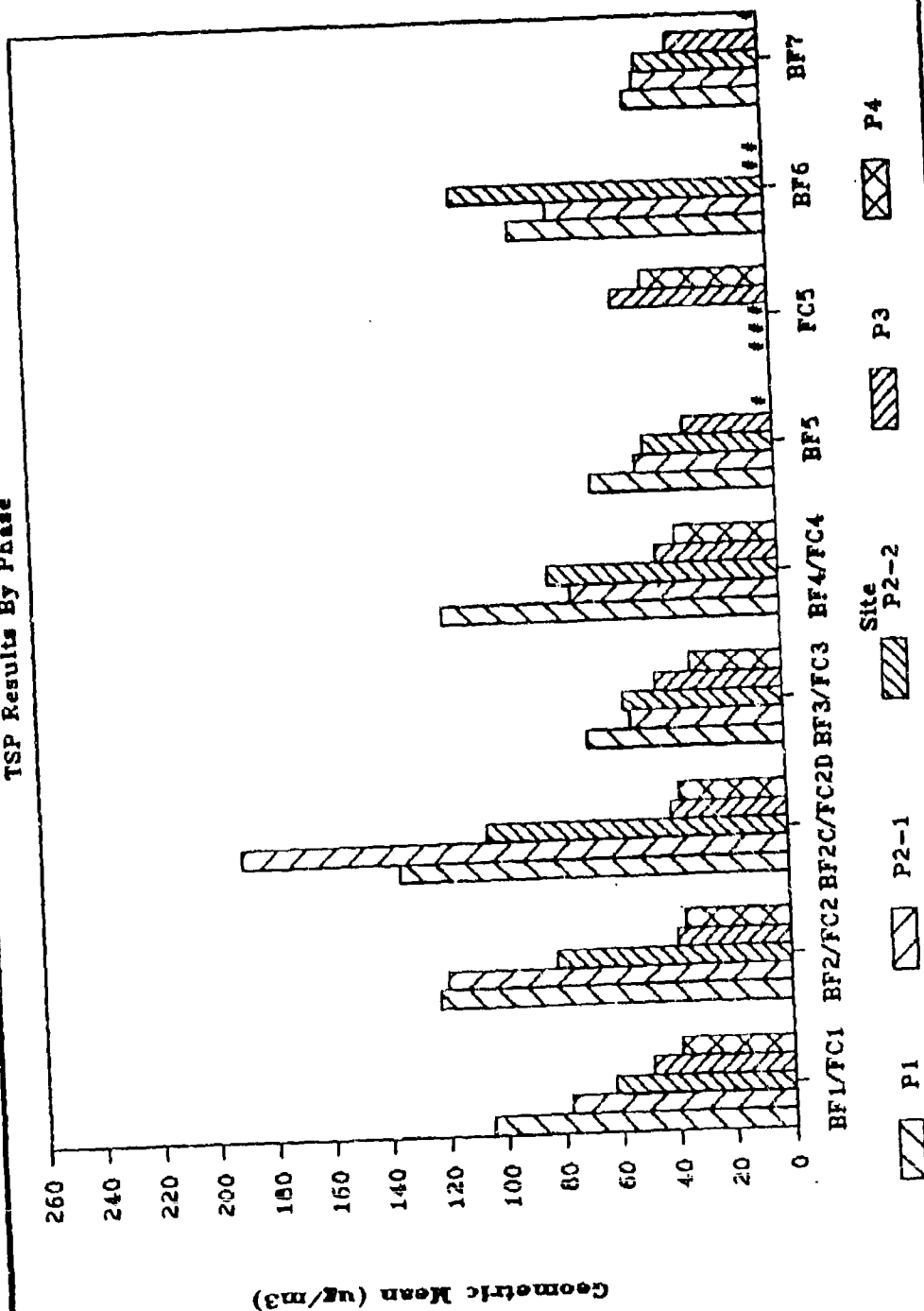


Figure 4.2-6
Basin F/IRA-F TSP
Results by Phase

CMP AR FY90

Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stoller & Associates, Inc.
Ebasco Services, Inc.

Individual station impacts reflect the distance from specific remedial activity. For example, BF1/FC1 located at the north end of the basin showed highest levels during the full remediation phase and dropped off to typical RMA baseline levels at the conclusion of remediation work. (All Basin F monitoring stations fell off to RMA background levels at the conclusion of remediation.) The geometric mean TSP concentration at BF1/FC1 was $105 \mu\text{g}/\text{m}^3$ during Phase 1, dropped to $78 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1, $62 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 2, $49 \mu\text{g}/\text{m}^3$ during Phase 3, and was $39 \mu\text{g}/\text{m}^3$ during the Phase 4 portion of the monitoring program. A maximum 24-hour concentration of $399 \mu\text{g}/\text{m}^3$ was measured at BF1 during the Phase 1 remediation period.

Station BF2/FC2, at the northeast perimeter of the Basin F compound, downwind of prevailing wind flow and in close proximity to extensive ground moving activities, measured the highest TSP concentrations during the remediation program. The geometric mean TSP concentration was $122 \mu\text{g}/\text{m}^3$ during Phase 1, $119 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1, $81 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 2, and then dropped to $39 \mu\text{g}/\text{m}^3$ during Phase 3 and $36 \mu\text{g}/\text{m}^3$ during the Phase 4 post-remedial period. Maximum 24-hour concentrations of $902 \mu\text{g}/\text{m}^3$ during Phase 1, $687 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1, and $514 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 2, were measured at this site on days when extensive remedial activity was proceeding adjacent to the monitoring station. The collocated Station BF2C/FC2D showed similar results.

Station BF3/FC3, at the southern perimeter of Basin F measured geometric mean TSP concentrations of 68, 53, 55, 44, and $32 \mu\text{g}/\text{m}^3$ respectively during Phase 1, Phase 2 Stage 1, Phase 2 Stage 2, Phase 3 and Phase 4. A maximum concentration of $286 \mu\text{g}/\text{m}^3$ was measured during the Phase 1 period. The lower TSP concentrations along the southern perimeter during the remediation periods can be attributed, to some extent, to the slightly greater distance from remedial and dirt moving activities. However, the primary explanation is the prevailing wind pattern experienced over the RMA area and the resultant pollutant dispersion pattern. The dispersion and meteorological influences are best illustrated in Figure 4.1-1, previously shown, which indicates the atmospheric dispersion pattern that corresponds to the Phase 1 monitoring period. The relationship between TSP levels, dispersion factors and remedial causal factors will be discussed in further detail in the next section for each phase of the remedial program. It is apparent from the dispersion pattern that the distribution of high TSP concentrations from the Basin F source is skewed to the north of the remedial activity. As noted, BF3/FC3 along the southern perimeter measured lesser TSP levels than the stations along the northern perimeter. This was also true during the Phase 4 FY90 period. Station FC3 measured a geometric mean value of $32 \mu\text{g}/\text{m}^3$ during this post-remedial period, while other monitoring stations to the north of the Basin measured geometric mean values 5 to $10 \mu\text{g}/\text{m}^3$ higher. The differences were not as

significant as during the remedial phases of the Basin F program, where, for example, FC2 to the north measured TSP levels three times those of FC3 to the south. Nevertheless, the data suggest that some minor residual TSP impacts remain over the remediated Basin F area. One explanation could be reseeding and other occasional construction activities over the area which temporarily loosened the soil. This was again true of other potential contaminants such as metals, VOCs and SVOCs that may have been emitted from Basin F (these will be discussed in subsequent sections).

Station BF4/FC4, along the northwest perimeter of Basin F, measured TSP levels equivalent to BF1/FC1 with the geometric mean value of $117 \mu\text{g}/\text{m}^3$ in Phase 1 decreasing to 42 and $35 \mu\text{g}/\text{m}^3$ during the Phase 3 and Phase 4 post-remedial periods. A maximum 24-hour TSP concentration of $324 \mu\text{g}/\text{m}^3$ was measured during the Phase 1 remediation period.

FC5 was installed during Phase 3 to the north of Basin F. This station measured the highest geometric mean ($44 \mu\text{g}/\text{m}^3$) and average value ($62 \mu\text{g}/\text{m}^3$) of the five IRA-F monitoring stations during the FY90 period. One explanation was the very high maximum 24-hour TSP value of $471 \mu\text{g}/\text{m}^3$ measured on September 14, 1990. As noted previously, very high TSP levels were measured across the Arsenal and throughout metropolitan Denver on this date as a result of a "limited mixing" weather event. Again, the very high value at FC5 may also have been associated with local construction and/or reseeding activities in the immediate vicinity of the monitoring station. This single day event to some extent skewed the annual averages to higher levels, particularly the arithmetic mean value, which is statistically more susceptible to individual events than the annual geometric mean value.

In summary, the conclusions of the Basin F TSP monitoring program are that during the remediation period the highest concentrations were confined to the immediate vicinity of the remedial activity and directly downstream from this activity as reflected by the atmospheric dispersion patterns. At the termination of the remediation activity, TSP levels at all monitoring stations were close to typical interior RMA baseline values, although slightly higher TSP levels were measured downstream from Basin F.

4.2.2.3 Analysis of Combined CMP/Basin F TSP Monitoring Results

Figures 4.2-7 and 4.2-8, which combine CMP and Basin F data for the Phase 1 and Phase 4 periods, provide a comprehensive depiction of TSP levels across RMA during the intense remediation period and the follow-on post-remediation periods, and reinforce conclusions obtained from analysis of the individual monitoring data. During Phase 1, the principal TSP impact was in close proximity to

Basin F remedial activity and downstream from the prevailing wind flow. BF2, at the northeast corner of Basin F and adjacent to much of the remedial activity, recorded the highest geometric mean value of $122 \mu\text{g}/\text{m}^3$ during the Phase 1 remedial period. On certain occasions, during periods of intense remediation activity and dirt hauling, 24-hour TSP levels reached as high as $600 \mu\text{g}/\text{m}^3$ to above $900 \mu\text{g}/\text{m}^3$ adjacent to the activity. (A maximum level of $902 \mu\text{g}/\text{m}^3$ was recorded at BF2 during Phase 1.) These high levels, however, were localized; TSP monitoring sites at distances of 1 mile or more from Basin F and at the RMA perimeters reflected little or no impact from the operations. During Phase 1, interior RMA CMP sites showed average and geometric mean values from $35 \mu\text{g}/\text{m}^3$ to $40 \mu\text{g}/\text{m}^3$ and 24-hour maximum values from $86 \mu\text{g}/\text{m}^3$ to $97 \mu\text{g}/\text{m}^3$. In fact, several of these stations were primarily influenced by other local and regional factors. This was especially true of CMP Stations AQ1 and AQ2 along the western and northwestern boundaries of RMA, which are the closest sites to metropolitan Denver. Prior to the Basin F remediation effort, these two stations measured the highest TSP levels of the 12 RMA monitoring sites (RI Monitoring Program, ESE, 1988). During Basin F remediation activity, TSP levels were significantly higher at the Basin F sites; however, during the post-remedial period AQ1 and AQ2 again measured the highest TSP levels across the RMA complex.

During the Phase 4 remedial period, the data reflected a significant decrease in Basin F concentrations that were more comparable to other RMA monitoring sites (and regional background levels). Note that the prevailing winds and dispersion patterns (as shown in Figures 4.1-1 through 4.1-5) were essentially the same as the early phases, and the conclusion must be that Basin F became a minor source of blowing dust. During Phase 4, AQ2 at the northwestern boundary of RMA reflected the highest mean and maximum values of the 17 TSP monitoring sites; this result is consistent with the pre-remedial monitoring results of the RI program (ESE, 1988). Also, note that almost all 24-hour maximum TSP values during the Phase 4 period occurred on September 14, 1990, the "limited mixing" episode previously discussed.

Figure 4.2-9 shows a bar graph distribution of TSP geometric mean values at the 12 CMP monitoring sites. Note that AQ10 and AQ11, immediately downwind from Basin F, and AQ12 adjacent to Borrow Pit dirt moving activities, show high TSP levels during the Phase 1 and Phase 2 remediation periods and then decrease significantly during the Phase 3 and Phase 4 post-remedial periods. Other RMA internal locations show little variation in geometric means throughout the remedial monitoring program. However, AQ1 and AQ2 at the western boundaries closest to metropolitan Denver, maintained moderately high TSP levels for all phases of the program.

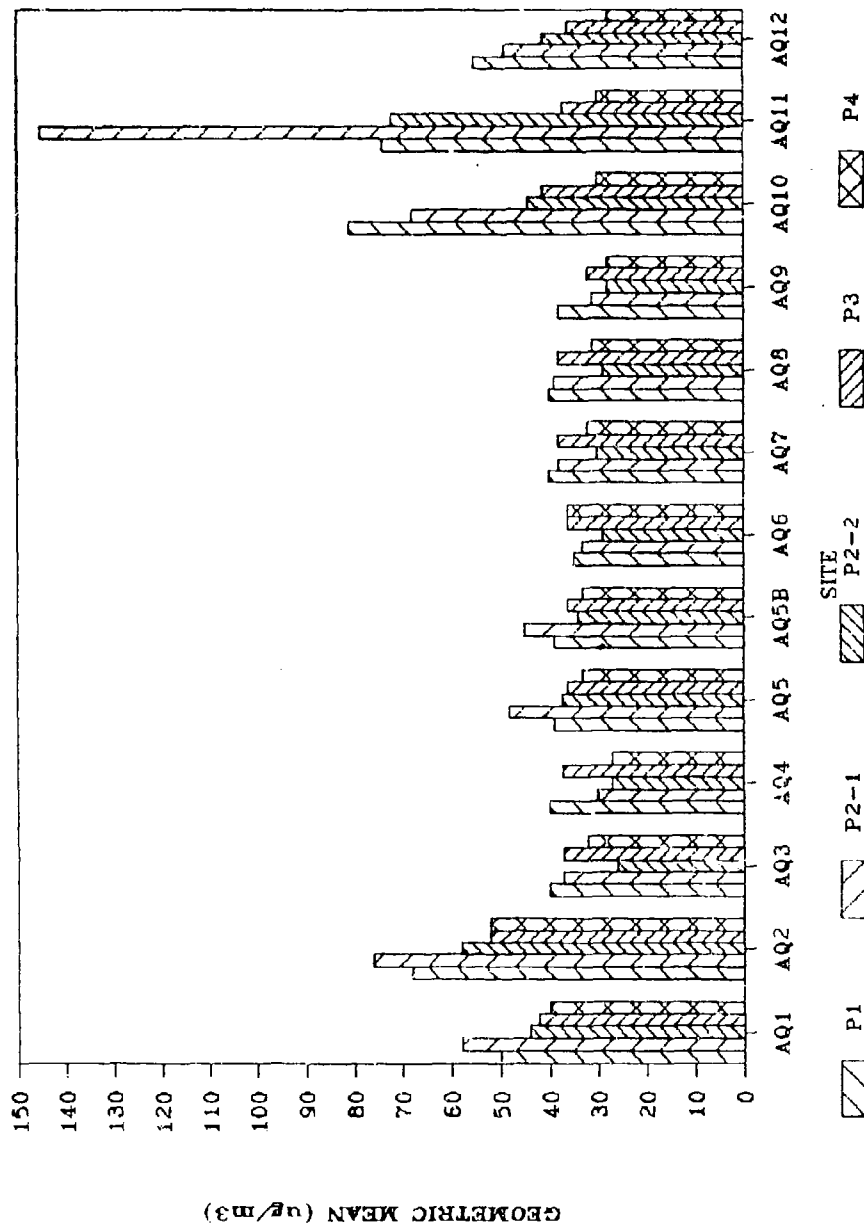


Figure 4.2-9
TSP Geometric Means by
Phase for CMP

CMP AR FY80

Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

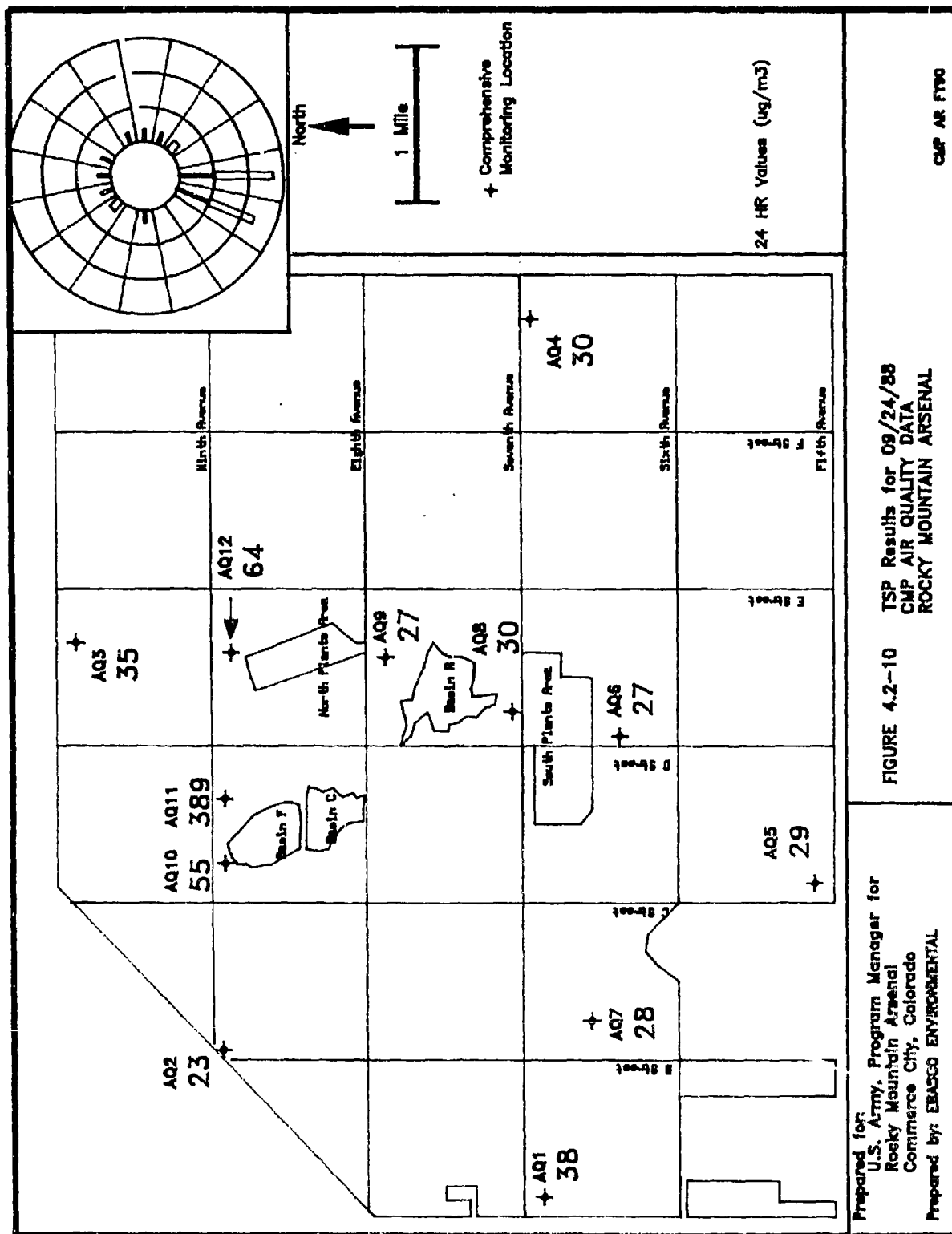
Another interesting aspect of the 31 months of RMA data is that TSP impacts were further reduced at all stations during the FY90 post-remedial monitoring period. This may partially be attributed to the remediation of Basin F; however, it is particularly evident from metropolitan Denver data that the fall-winter period of 1989-90 was less severe with respect to inversion and brown cloud conditions. The stations most influenced by Basin F activity, AQ10, AQ11, and AQ12, had TSP levels that were reduced significantly from Phases 1 and 2 (by a factor of over 2.5 at AQ10), while those stations at greater distances from Basin F showed smaller decreases. This reflects slightly decreasing impacts from Basin F, but primarily shows the anomalous trend of the 1989-90 fall-winter inversion season.

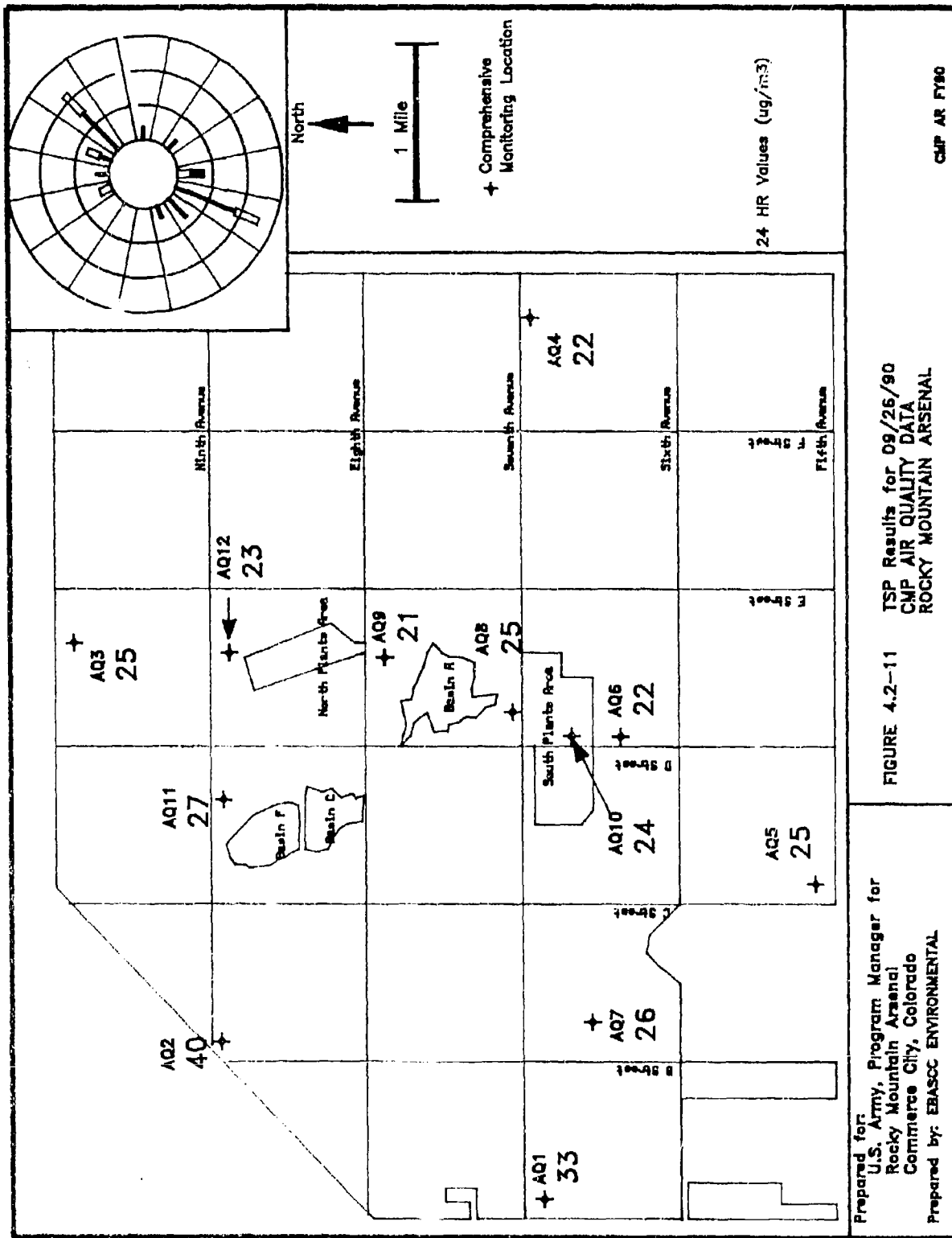
4.2.2.4 Individual Day Remedial Assessment Comparisons

It is important to note that individual daily impacts varied substantially, depending upon the specific meteorological conditions and the specific remediation activity. Figure 4.2-10, for example, shows a Phase 1 day (September 24, 1988) when light to moderate winds were blowing across Basin F from the south and southwest for several hours in the direction of the AQ11 monitor at the northeast corner of the Basin F perimeter. Most other wind directions throughout the day were variable. The wind rose (in the top right corner of the figure) indicates the frequency of occurrence of wind speed and wind direction. Station AQ11 reported a TSP level of $389 \mu\text{g}/\text{m}^3$ for this 24-hour period; Station AQ12, also downwind from Borrow Pit activity, reported $64 \mu\text{g}/\text{m}^3$. All other stations reported relatively low TSP values. AQ10, close to Basin F but not directly downwind from the apparent source, measured $55 \mu\text{g}/\text{m}^3$. AQ3, farther downwind, reported $35 \mu\text{g}/\text{m}^3$, indicating that the high TSP values were primarily a function of *local remediation activity* that fell off quickly with distance from the source. All stations upwind from Basin F measured considerably lower values. During a Phase 4 day on September 26, 1990, again with prevailing southerly wind conditions, all TSP values across RMA were at low levels including the previously impacted Basin F sites (see Figure 4.2-11). The wind rose shown on this figure suggests modest potential impacts from a Basin F source; however, this was not reflected by concentrations measured at AQ11 on this post-remedial day.

4.2.3 RMA TSP CAUSAL EFFECTS

The impacts of metropolitan Denver on Arsenal TSP levels will be discussed further in Section 4.2.4. Several studies were also conducted during CMP FY88 and FY89 relating the impacts of wind gusts and source locations to TSP concentrations measured at the various monitoring locations. This section provides a brief update on the status of these investigations. The causal effects of TSP concentrations



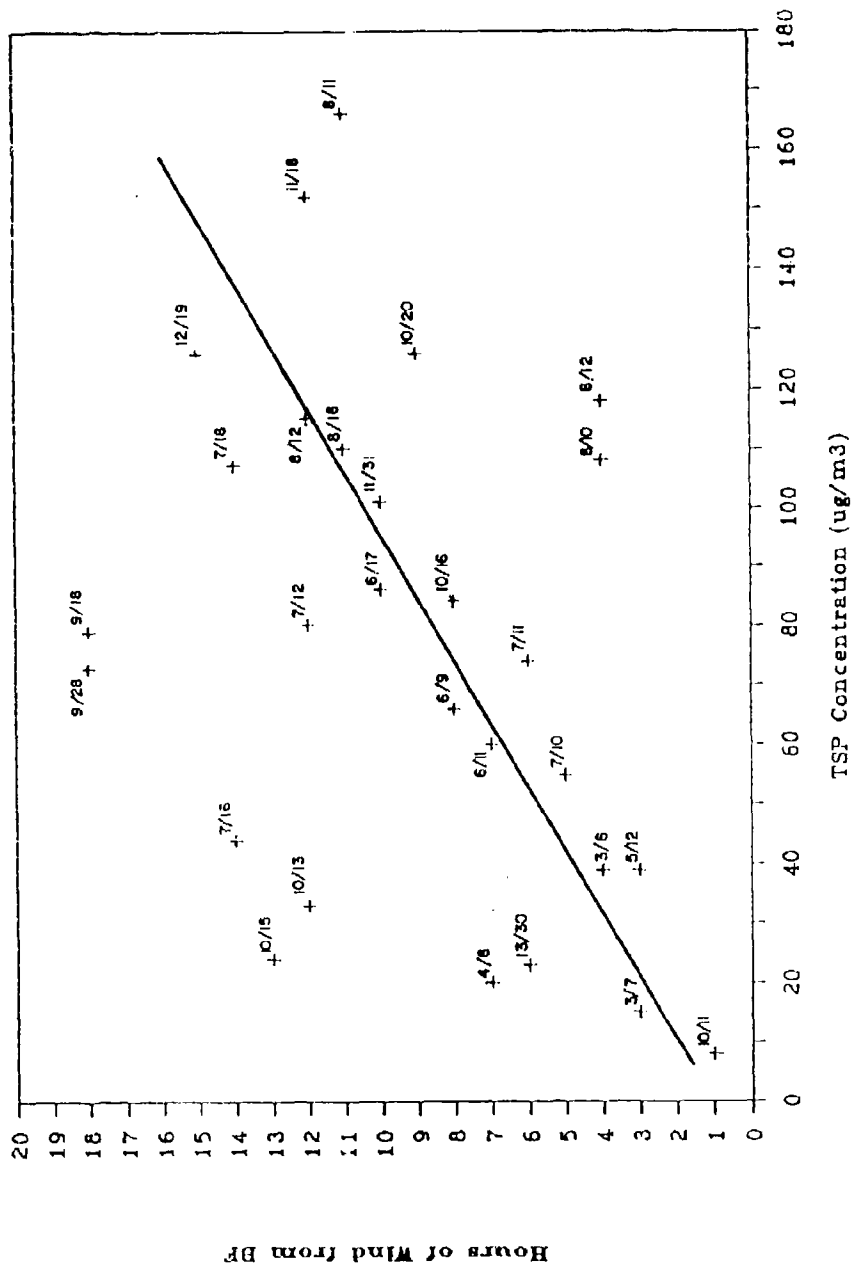


at RMA monitoring sites are varied and cannot be reduced to two or three sources or unique meteorological events. The impacts of Basin F remediation activity were described in detail in the previous sections. The impacts from metropolitan Denver are also significant and will be discussed further in Section 4.2.4. Other factors such as wind speed, wind direction, precipitation, inversion conditions, seasonal and climatological effects, as well as variable construction and remediation activity at the Arsenal all influence the short-term and long-term monitoring results.

In the CMP FY88 Data Assessment Report, a direct correlation was established between 24-hour TSP levels and strong winds blowing downwind from a remediation source. During the FY88 remediation period, AQ11 downwind from Basin F showed a correlation of 0.4 between TSP levels and winds blowing from the Basin toward the station ($\pm 30^\circ$), as shown in Figure 4.2-12. Further downstream at other RMA sites, the relationship was no longer evident, indicating that these causal effects were not only wind speed and wind direction dependent, but also distance dependent. The data suggest that at a distance of 1 mile, remediation impacts became minimal. During FY89 when the Basin F remediation work was completed, the correlation between high TSP levels at AQ11 and winds blowing off Basin F (shown in Figure 4.2-13) was no longer observed (the correlation was -0.03). It is apparent from the observed data that Basin F was a major TSP source during the remediation activity, but was eliminated during the post-remedial period except for minor residual impacts associated with continuing reseeded and construction activities.

A long-term statistical analysis of the RMA data should also document and consider unique remediation and construction activities associated with the data collection period. For example, during FY88 and FY89 the Borrow Pit, which was used as fill dirt for Basin F remediation, contributed significantly to TSP levels measured at AQ12; however, these levels decreased in FY90. Activity from the Lower Derby Lake spillway area strongly influenced TSP levels at AQ6 in FY90.

In addition to remediation source influences, seasonal and climatological conditions also influenced the data reported. Although some of these effects can be identified in the 31-month database, local and unique meteorological events have overriding influences. Table 4.2-5 shows seasonal TSP results (average and 24-hour maximum concentrations) for each of the RMA monitoring sites. The highest Arsenal TSP concentrations occurred in the summer, the lowest in spring, and moderate levels occurred in both fall and winter. At AQ1, AQ2, and AQ5 on the west, northwest, and southern boundaries which are closest to metropolitan Denver influences, the highest concentrations occurred in the fall or winter, while the interior Arsenal monitoring sites experienced the highest TSP concentrations during the summer period (exclude Basin F impacted sites AQ10 and AQ11).



Prepared for:

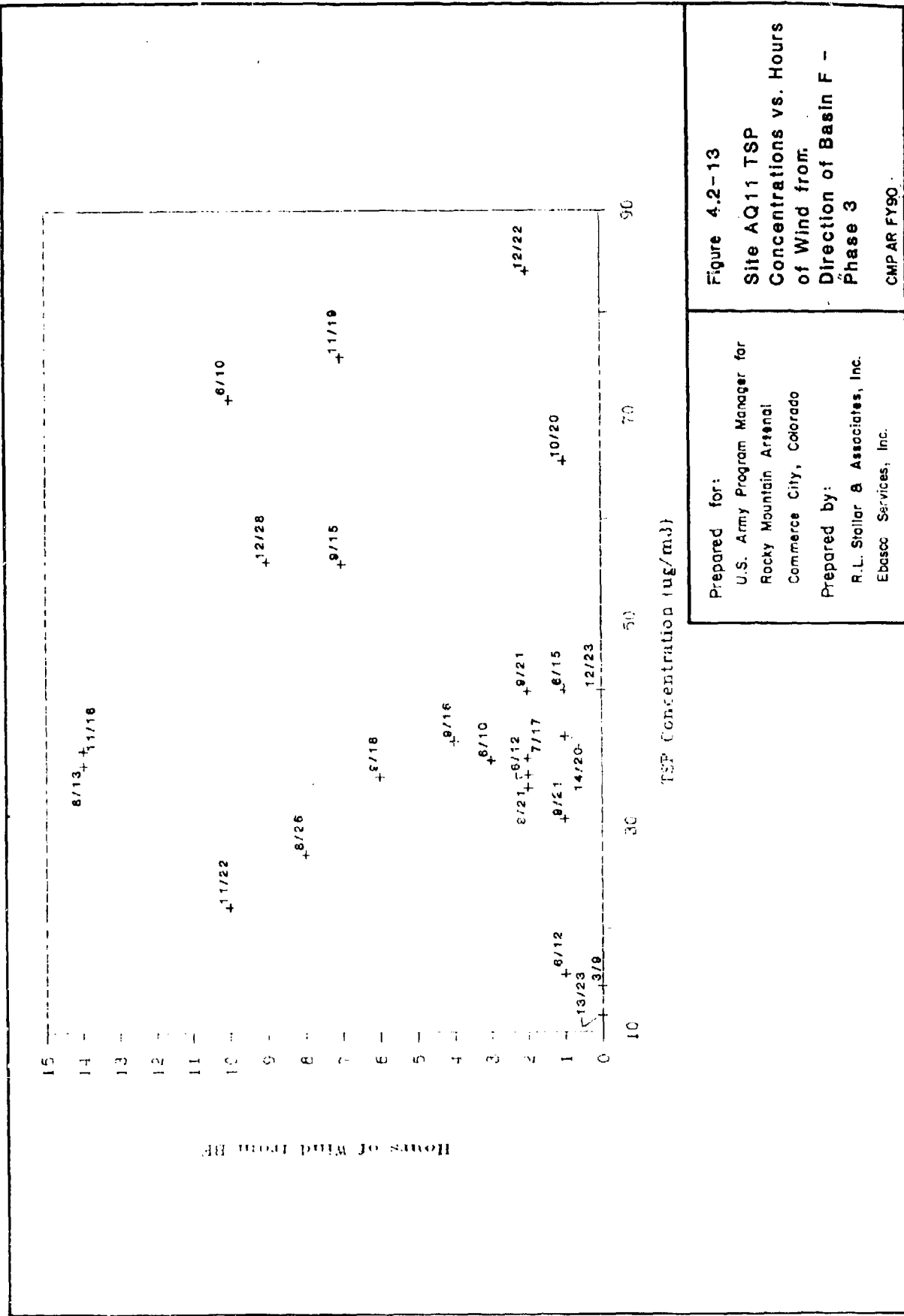
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 4.2-12

Site AQ 11 TSP
Concentrations vs. Hours
of Wind from Direction
of Basin F-Phase 1
CMPAR FY90



Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 4.2-13
Site AQ11 TSP
Concentrations vs. Hours
of Wind from
Direction of Basin F -
Phase 3
CMPAR FY90

Table 4.2-5 Combined Seasonal TSP Concentrations (in $\mu\text{g}/\text{m}^3$)

	Fall	Winter	Spring	Summer
AVERAGE				
AQ1	62	56	40	53
AQ2	84	68	50	75
AQ3	44	34	33	52
AQ4	40	29	27	47
AQ5	44	51	35	44
AQ5B	44	48	34	45
AQ6	39	35	46	55
AQ7	44	38	34	46
AQ8	40	36	35	47
AQ9	39	33	32	41
AQ10	70	52	40	68
AQ11	88	114	48	66
AQ12	52	63	37	68
SEASONAL AVERAGE	53	50	38	54
24-HOUR MAXIMUM				
AQ1	134	179	88	184
AQ2	162	198	118	208
AQ3	98	113	95	194
AQ4	79	102	52	171
AQ5	96	183	87	170
AQ5B	93	172	83	181
AQ6	84	143	396	321
AQ7	91	156	86	180
AQ8	84	130	87	188
AQ9	85	127	93	164
AQ10	279	175	122	252
AQ11	542	738	214	388
AQ12	165	467	238	590
SEASONAL MAXIMUM	542	738	396	590

Metropolitan Denver influenced the Arsenal most in the fall and winter during intense inversion periods.

Seasonal data also reflect the unique influences of remediation activity at sites AQ10, AQ11, and AQ12. For example, AQ11 experienced especially high concentrations during Basin F cleanup work on several winter days, including a maximum reported concentration of $738 \mu\text{g}/\text{m}^3$. Station AQ12 was directly impacted by Borrow Pit activity during the summer of FY88 (maximum of $590 \mu\text{g}/\text{m}^3$), resulting in a high overall summer seasonal TSP concentration at this station. During FY90, construction activities at the Lower Derby Lake spillway resulted in very high concentrations during the spring and summer months at AQ6, downwind from the activity. The highest seasonal concentrations at this site occurred during the spring and summer seasons.

Table 4.2-6 is a more detailed breakdown of seasonal trends for 10 consecutive quarters from the spring of FY88 to the fall of FY90. Average concentrations and 24-hour maximum levels varied considerably, depending upon both the source influences and the unique meteorological events. Maximum values identified the impacts of Basin F remediation AQ10, AQ11 and AQ12 during the first few quarters, as well as the impacts at AQ6 during the spring and summer quarters of FY90. The variability of unique meteorological events was portrayed during the winter of FY89 and the summer of FY90, when extremely high TSP concentrations occurred across the Denver metropolitan area and the Arsenal on February 9, 1989, and September 14, 1990, influencing both maximum concentrations and seasonal averages.

Rather than identifying strong seasonal trends, these data confirm the overriding influence of individual source impacts and meteorological events. As the database is expanded, individual events will be filtered out and certain seasonal impacts may become more apparent. As a preliminary generalization, one may anticipate higher TSP concentrations at perimeter stations close to metropolitan Denver, especially at AQ1 and AQ2, during the fall and winter periods. On the other hand, higher summer TSP concentrations may be anticipated at Arsenal interior stations due to more frequent construction activity, creating soil conditions that are more favorable to blowing dust.

Table 4.2-6 Seasonal TSP Concentrations by Site (in $\mu\text{g}/\text{m}^3$) (continued)

	24-HOUR MAXIMUM											
	FY88				FY89				FY90			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
AQ1	88	105	134	179	64	82	133	85	61	184		
AQ2	118	196	162	198	85	130	161	102	91	208		
AQ3	95	96	93	113	51	82	98	67	61	194		
AQ4		120	79	102	45	92	73	46	52	171		
AQ5	87	82	82	183	53	79	96	124	53	170		
AQ5B	83	81	83	172	48	78	93	122	56	181		
AQ6	86	78	71	143	54	76	84	64	396	321		
AQ7	86	91	73	156	49	78	91	76	60	180		
AQ8	87	87	76	130	78	84	84	68	64	188		
AQ9	93	89	85	127	41	76	76	67	51	164		
AQ10		252	279	175	122	90	100	70	41			
AQ11	166	388	542	738	214	84	97	70	57	214		
AQ12	238	590	165	467	90	86	82	63	62	167		

4.2.4 DENVER METROPOLITAN AREA TSP INFLUENCES

4.2.4.1 CMP FY90 Period Results

It is evident from these assessments that RMA activities were not the only TSP sources that influenced the Arsenal and its adjacent boundary areas. As previously noted, the 1986-1987 Remedial Investigation study clearly established that prior to remediation, TSP values were highest at the perimeter stations and lowest in the interior of the Arsenal, suggesting that the principal long-term major sources in the area were the industrial or transportation activities of metropolitan Denver. The Basin F Remediation Program temporarily altered this situation at several sites in the interior of RMA; however, Denver was still a major contributor.

Table 4.2-7 shows the major stationary sources with TSP emissions of 25 tons per year (tpy) or more surrounding the Arsenal. Several of the sources are located within 2 miles to the west and southwest of RMA, as shown in Figure 4.2-14, and contribute a large portion of the total TSP emissions for Adams, Arapahoe, and Denver counties (CDH, 1990). Compared to the major TSP sources, the Arsenal accounts for a small fraction of the total TSP emissions. In addition to these external stationary sources, dust from vehicle traffic and off-roads sources contributes greatly to the TSP emissions.

Table 4.2-8 is a summary of Denver metropolitan area TSP data measured concurrently with the FY90 program as well as with the Basin F remediation phases. Figure 4.2-15 shows the geographic distribution of TSP geometric mean levels across the metropolitan area, including RMA for FY90. As noted, the highest levels were in the downtown area at CAMP (2105 Broadway), where TSP concentrations have exceeded the ambient air quality primary and secondary standards for the past 15 years or more. During 1989, maximum 24-hour TSP concentrations in downtown Denver frequently exceeded the 24-hour standard of $150 \mu\text{g}/\text{m}^3$. A maximum level of $472 \mu\text{g}/\text{m}^3$ was recorded at CAMP on January 4, 1989. During FY90, the annual geometric mean at CAMP was $101 \mu\text{g}/\text{m}^3$, well above the annual standard of $60 \mu\text{g}/\text{m}^3$; the maximum 24-hour TSP concentration was $363 \mu\text{g}/\text{m}^3$, again exceeding the 24-hour primary and secondary standards.

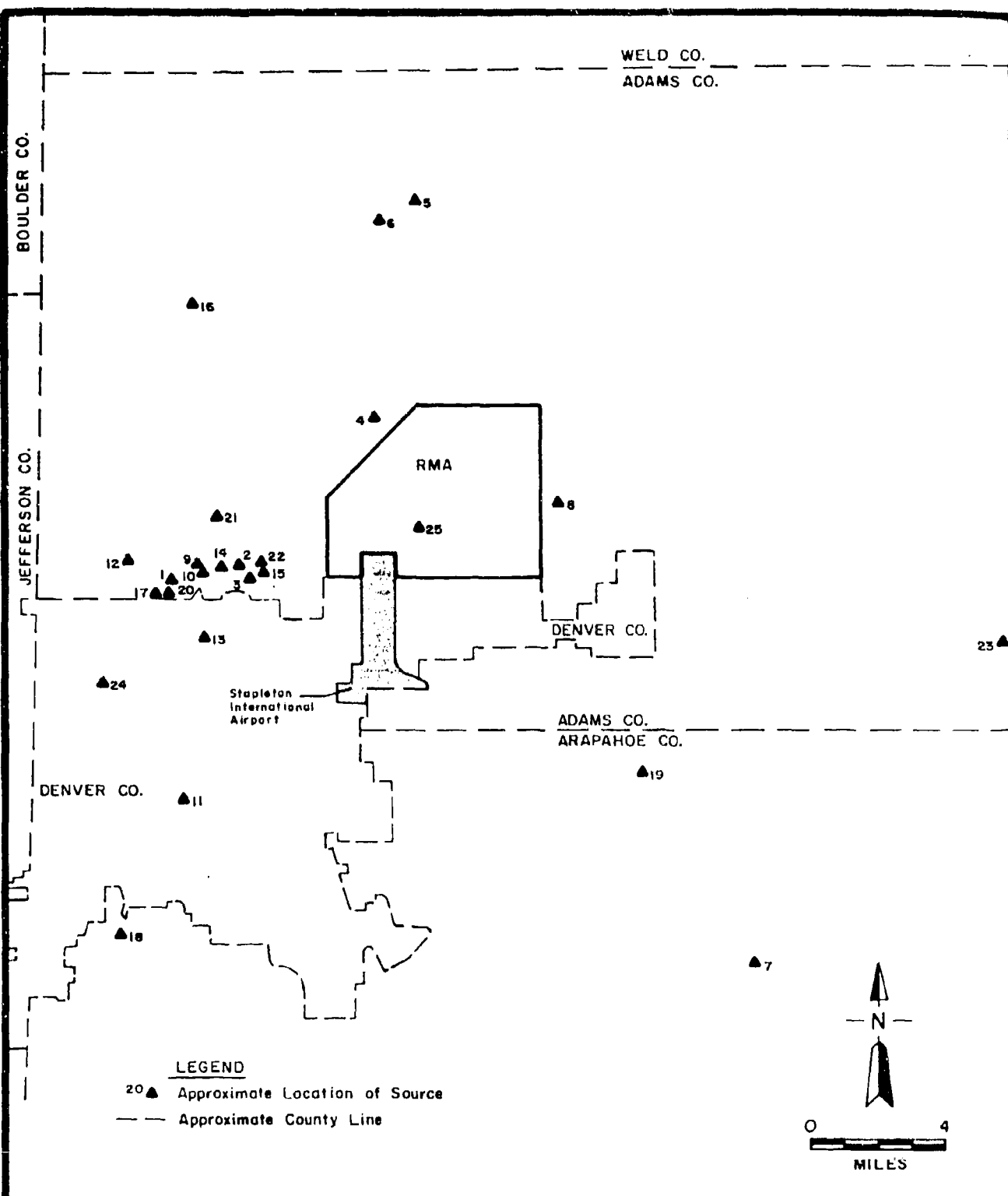
Other Denver TSP monitoring stations also exceeded the 24-hour and annual standards. On several occasions, under intense inversion conditions, high TSP levels from the general metropolitan area also engulfed the Arsenal. Figure 4.2-2, previously discussed, depicts a day, September 14, 1990, when all RMA monitoring sites were in excess of $100 \mu\text{g}/\text{m}^3$. Maximum TSP concentrations on this day

Table 4.2-7 Particulate Sources with Emissions of 25 TPY or More

County	UTM/E	UTM/N	Plant Name	Emissions (tpy)	Percent Tri-County Total	Percent of State Total
Adams	501.7	4404.8	1 Asarco Incorporated	370	16.3	0.6
Adams	503.0	4406.2	2 PSCO Cherokee Plant	213	9.4	0.3
Adams	504.5	4405.5	3 Conoco Inc.	116	5.1	0.2
Adams	507.9	4412.2	4 Purina Mills	98	4.3	0.2
Adams	512.7	4420.5	5 Brannan Sand & Gravel	78	3.4	0.1
Adams	511.8	4418.5	6 Zignan Sand & Gravel	53	2.3	0.1
Arapahoe	531.5	4386.5	7 Coal Creek Resources	49	2.2	0.1
Adams	519.5	4409.9	8 Landfill Inc.	46	2.0	0.1
Adams	505.2	4406.3	9 Denver Feed & Grain	46	2.0	0.1
Adams	505.5	4406.1	10 Boyles Galvanizing Co.	46	2.0	0.1
Denver	499.6	4389.8	11 Robinson Brick & Tile	45	2.0	0.1
Adams	499.7	4406.9	12 Western Paving Constr.	43	1.9	0.1
Denver	502.1	4402.3	13 Conagra - Wynkoop	42	1.9	0.1
Adams	503.6	4406.8	14 Conagra	38	1.7	0.1
Adams	505.3	4405.7	15 Fast Construction Co.	32	1.4	0.1
Adams	501.1	4418.9	16 American Fertilzr. & Chem.	31	1.4	0.1
Adams	500.9	4404.0	17 South Dakota Cement	31	1.4	0.1
Arapahoe	499.0	4385.8	18 Electron Corporation	31	1.4	0.1
Arapahoe	520.0	4395.6	19 US Govt. Buckley Air Base	28	1.2	
Adams	501.0	4404.5	20 Cobitco	27	1.2	
Adams	505.8	4409.4	21 Front Range Asphalt	27	1.2	
Adams	504.7	4405.8	22 Colorado Refining Co.	26	1.1	
Adams	610.0	4401.5	23 Hwy. 36 Land Dev. - BFI	25	1.1	
Denver	498.7	4397.9	24 ABEX Corp. Cast Products	25	1.1	
Adams	513.6	4408.3	25 RMA	1		
TRI-COUNTY TOTALS				2264	69.2	
STATE TOTALS				61492		2.3

Source: Colorado Department of Health EISPS Inventory, May 1990.

Legend: UTM/E = Universal Transverse Mercator east coordinate
UTM/N = Universal Transverse Mercator north coordinate
tpy = tons per year



Prepared for:

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.
Ebasco Services Inc.

Figure 4.2-14

Particulate Sources with Emissions of
25 tpy or More in RMA Vicinity

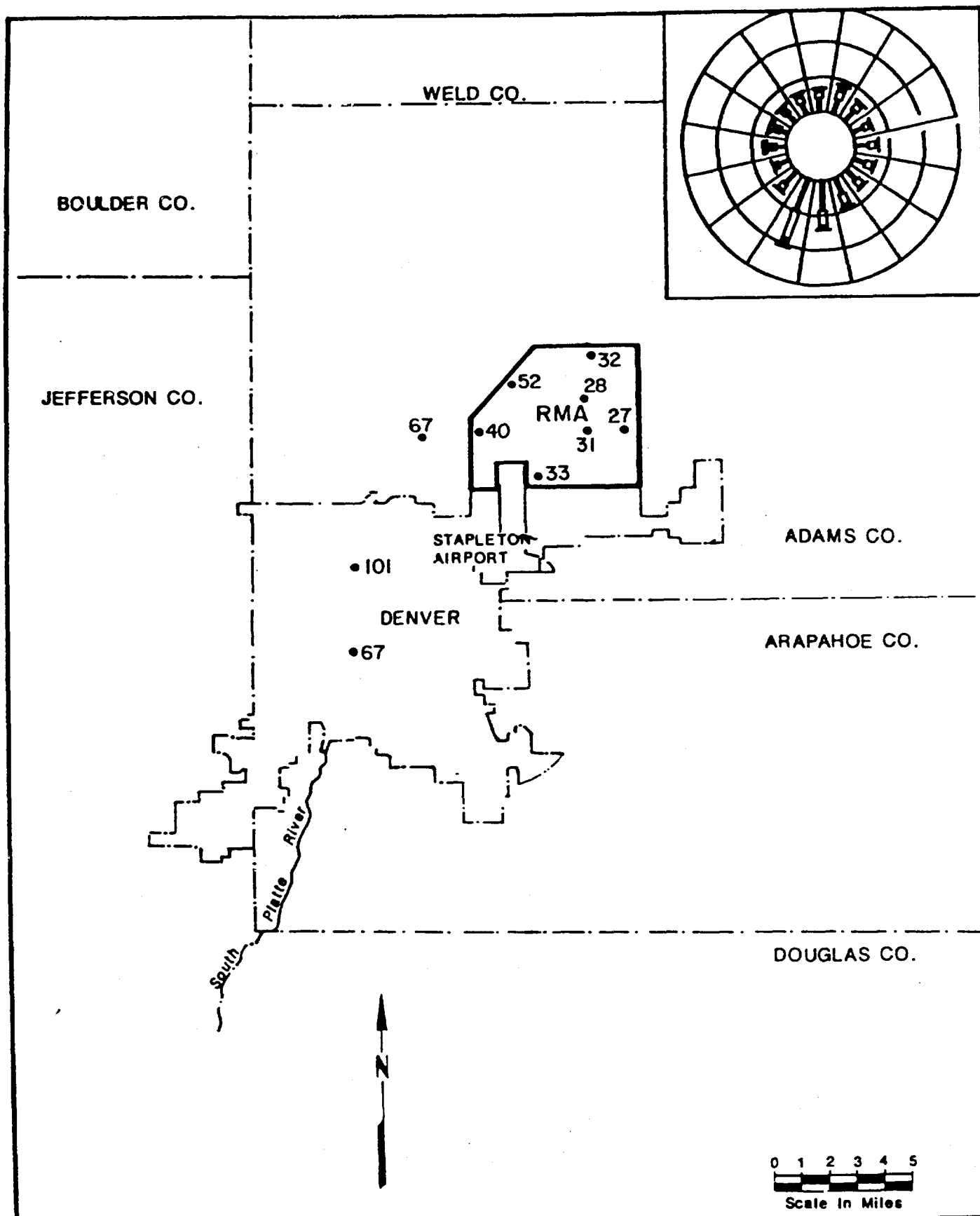
Table 4.2-8 Denver Metropolitan Area Total Suspended Particulates (TSP) (in $\mu\text{g}/\text{m}^3$)

Station	Phase 1	Phase 2-1	Phase 2-2	Phase 3	Phase 4 (FY90)
GEOMETRIC MEANS					
Adams City	87.3	103.0	61.2	71.0	66.8
414 14th Street	83.7	137.4	--	--	*
CAMP/2105 Broadway	107.9	192.2	132.2	98.9	100.8
1050 S. Broadway	74.1	135.2	93.7	63.4	66.6
208 3rd Street	62.9	62.7	57.0	90.2	*
4857 S. Broadway	64.4	84.9	--	--	*
24-HOUR MAXIMUM VALUES					
Adams City	283.0	244.0	85.0	131.0	206.0
414 14th Street	242.0	183.0	--	--	*
CAMP/2105 Broadway	260.0	472.0	256.0	149.0	363.0
1050 S. Broadway	162.0	278.0	162.0	100.0	287.0
208 3rd Street	153.0	179.0	144.0	385.0	*
4857 S. Broadway	152.0	94.0	--	--	*

* Samples are no longer collected at this station.

Annual geometric mean standard is $75 \mu\text{g}/\text{m}^3$.
 Second-maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$.

Phase 1 is from March 22 to December 12, 1988.
 Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.
 Phase 2, Stage 2 is from February 16 to May 5, 1989.
 Phase 3 is from May 6 to September 30, 1989.
 Phase 4 is from October 1, 1989 through September 30, 1990.



Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates

Figure 4.2-15

Denver Area TSP Data for FY90
Geometric Means ($\mu\text{g}/\text{m}^3$)

CMP AR FY 90

were 205 $\mu\text{g}/\text{m}^3$ at CAMP and 196 $\mu\text{g}/\text{m}^3$ at 1050 S. Broadway in Denver. The wind rose pattern shown in Figure 4.2-2 reflects the bimodal flow of pollutants from the southeast in the morning to a northwesterly flow during the afternoon. Pollutants that dispersed northwestward were carried back into the area when the wind shifted in the afternoon.

As a general rule, concentrations fell off from the center of Denver and were typically about 50 percent lower in the outlying suburbs, including RMA. During 1986-1987 prior to Basin F remediation activity, the average concentration at RMA for *all sites* was 40 $\mu\text{g}/\text{m}^3$. The boundary sites, AQ1 and AQ2, averaged 56 $\mu\text{g}/\text{m}^3$ and were comparable to other suburban measurements, whereas the interior RMA sites averaged 38 $\mu\text{g}/\text{m}^3$. As noted, this condition was temporarily altered during Basin F remediation activities. However, during the FY90 post-remedial monitoring period, the average TSP concentration for all CMP sites was 41 $\mu\text{g}/\text{m}^3$, with the boundary sites averaging 55 $\mu\text{g}/\text{m}^3$ and the interior sites averaging 38 $\mu\text{g}/\text{m}^3$. These results are almost identical to the pre-remedial monitoring results at RMA.

One important difference between high TSP values measured in metropolitan Denver and those at RMA is that those experienced in metropolitan Denver were frequently associated with high pollution episodes in which industrial and vehicle traffic emissions were trapped under a blanketing inversion that spread across the area. In these cases winds were generally light to moderate. Occasionally, these metropolitan Denver impacts extended to the vicinity of RMA; however, during remedial operations at RMA, higher concentrations were invariably associated with strong wind gusts that lifted dirt which had been loosened by handling.

4.2.5 ANALYSIS IMPLICATIONS FOR MITIGATION AND CONTROLS

The general results of these investigations indicate that many of the RMA sources were localized and that although very high concentrations were frequently measured adjacent to remedial activities, concentrations fell off considerably with distance from the source. Consequently, those sources well into the RMA interior were less likely to cause impacts off the Arsenal, while those sources closer to the boundaries were more likely to cause temporary impacts at the boundary when strong or gusty winds were blowing in the appropriate direction.

Also, certain atmospheric conditions and diurnal factors can spread pollutants greater distances from the disturbing source. The ongoing CMP and the summarized results, with emphasis on causative factors, form the basis for practical mitigating actions. For example, when monitoring shows

excessive TSP levels, chemical stabilizers, covers, reseeded, and landscaping can be used over sensitive areas, as in the case of Basin F and Basin A, and dirt excavation, hauling and unloading can be minimized during periods of high winds and poor dispersion potential (as reflected by air quality models), particularly when impacts would be towards nearby boundaries.

4.2.6 SUMMARY

TSP levels at RMA can be attributed to two principal sources: (1) the influx of industrial or urban traffic emissions from metropolitan Denver, and (2) remedial activity producing wind-blown dust, usually during high wind episodes. Because of increased remedial activity at RMA during the FY88 and FY89 CMP monitoring periods, there was a noticeable increase in TSP levels at sites adjacent to or directly downwind from construction work, primarily at Basin F. However, the impacts from the Arsenal-generated sources were localized and fell off rapidly with distance from the source. During FY90 after the termination of the Basin F cleanup program, TSP concentrations downwind from Basin F decreased significantly.

4.3 RESPIRABLE PARTICULATE MATTER

4.3.1 CMP PM-10 MONITORING PROGRAM

Respirable particulate matter, those particles with aerodynamic diameters less than 10 microns, referred to as PM-10, was monitored at five separate locations for the FY90 monitoring period. A collocated monitor also operated at Site AQ5 during the program. Two additional monitors were added to the network during FY89 and were continued during FY90 because of the increased emphasis placed on PM-10 impacts by the EPA and other regulatory agencies. Authorization was received through a modification in the CMP Technical Plan in late FY90 to include two portable PM-10 monitors in the network. The first portable station was established downwind from the South Plants subdrain activity at AQ10. Monitoring was initiated on September 8, 1990, and four samples were collected during the remainder of FY90. A synopsis of the PM-10 monitoring effort for FY90 is given in Table 4.3-1.

Table 4.3-1 Summary of RMA CMP FY90 Sampling for Respirable Particulates of Less Than 10 Microns (PM-10)

Station	Number of Samples	Percent Recovery
AQ1	59	97
AQ2	60	98
AQ3	60	98
AQ5	57	93
AQ9	56	92
AQ10	4	100
AQ5D ¹	58	95
PROGRAM TOTAL	354	96

1 AQ5D is a collocated station. The intent and operation of collocated stations are discussed in Section 8.4, Quality Assurance.

Average and 24-hour maximum concentrations for the CMP FY90 PM-10 program are shown in Table 4.3-2. As shown previously in Table 2.1-1, the annual PM-10 standard is an arithmetic mean of $50 \mu\text{g}/\text{m}^3$, and the 24-hour standard is $150 \mu\text{g}/\text{m}^3$. Twenty-four hour sequential data are provided in Appendix B. There were no exceedances of the PM-10 annual or 24-hour ambient air quality standards at RMA during FY90.

During FY90, PM-10 annual arithmetic mean and 24-hour maximum values were considerably lower than FY89 levels at all five permanent RMA monitoring sites (AQ1, AQ2, AQ3, AQ5 and AQ9). The maximum 24-hour PM-10 values occurred at all sites on September 14, 1990. This is the same day that produced high TSP levels, as discussed in Section 4.2.1. Excluding portable site AQ10 which operated on only four sample days, the highest concentrations were measured at the boundaries of the Arsenal. AQ2, at the northwestern boundary and closest to Commerce City traffic, measured the maximum annual average of $25 \mu\text{g}/\text{m}^3$ compared to a value of $33 \mu\text{g}/\text{m}^3$ in FY89. The highest 24-hour level was $90 \mu\text{g}/\text{m}^3$ at AQ10 compared to a maximum 24-hour concentration of $168 \mu\text{g}/\text{m}^3$ in FY89.

Table 4.3-2 Concentrations of Respirable Particulates of Less Than 10 Microns (PM-10) for CMP FY90 (in $\mu\text{g}/\text{m}^3$)

Month	AQ1	AQ2	AQ3	AQ5C	AQ5D	AQ9	AQ10
Summary of Arithmetic Mean Concentrations *							
October	39	40	32	29	29	28	
November	28	25	22	20	20	18	
December	20	22	15	20	20	15	
January	22	21	16	24	24	12	
February	22	32	24	26	26	23	
March	15	14	12	13	11	12	
April	17	17	14	18	14	13	
May	18	17	14	15	15	16	
June	23	28	21	22	21	22	
July	17	20	20	12	15	15	
August	26	28	22	22	21	21	
September	29	31	26	25	25	26	36
ANNUAL	23	25	20	21	20	19	36
Summary of 24-Hour Maximum Concentrations **							
October	67	66	56	50	51	43	
November	43	35	35	30	30	29	
December	25	30	20	26	25	17	
January	44	33	24	66	66	22	
February	28	75	59	60	60	57	
March	22	27	15	18	17	16	
April	32	34	25	28	29	25	
May	25	24	20	24	24	29	
June	37	44	33	30	30	37	
July	25	29	24	18	21	26	
August	37	42	34	33	33	30	
September	72	81	72	65	67	71	90
ANNUAL	72	81	72	66	67	71	90

* Annual arithmetic mean standard is $50 \mu\text{g}/\text{m}^3$.

** Maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$.

Note: FY90 is the period from October 1, 1989 to September 30, 1990.
The PM-10 sampler at AQ10 was installed on September 5, 1990.

In general, the highest PM-10 concentrations occurred in the fall and winter periods at most sites. Since there were no significantly high episodes of PM-10 concentrations in FY90, the monthly differences were not as striking as in the previous 2 years. The highest monthly concentrations were reported in October when $40 \mu\text{g}/\text{m}^3$ was measured at AQ2 and $39 \mu\text{g}/\text{m}^3$ was measured at AQ1. The highest concentration on a single day ($90 \mu\text{g}/\text{m}^3$) occurred on September 14, 1990. This day was somewhat anomalous, as noted in Section 4.2.1. Temperatures were below normal, winds were light, and inversion conditions were intense, reflecting both a surface inversion and an intense upper air "limited mixing" inversion at about 4,000 feet above the ground (see Figure 4.2-3). The widespread impact of this meteorological phenomenon on PM-10 concentrations across the Denver metropolitan area and the Arsenal are shown in Figure 4.3-1.

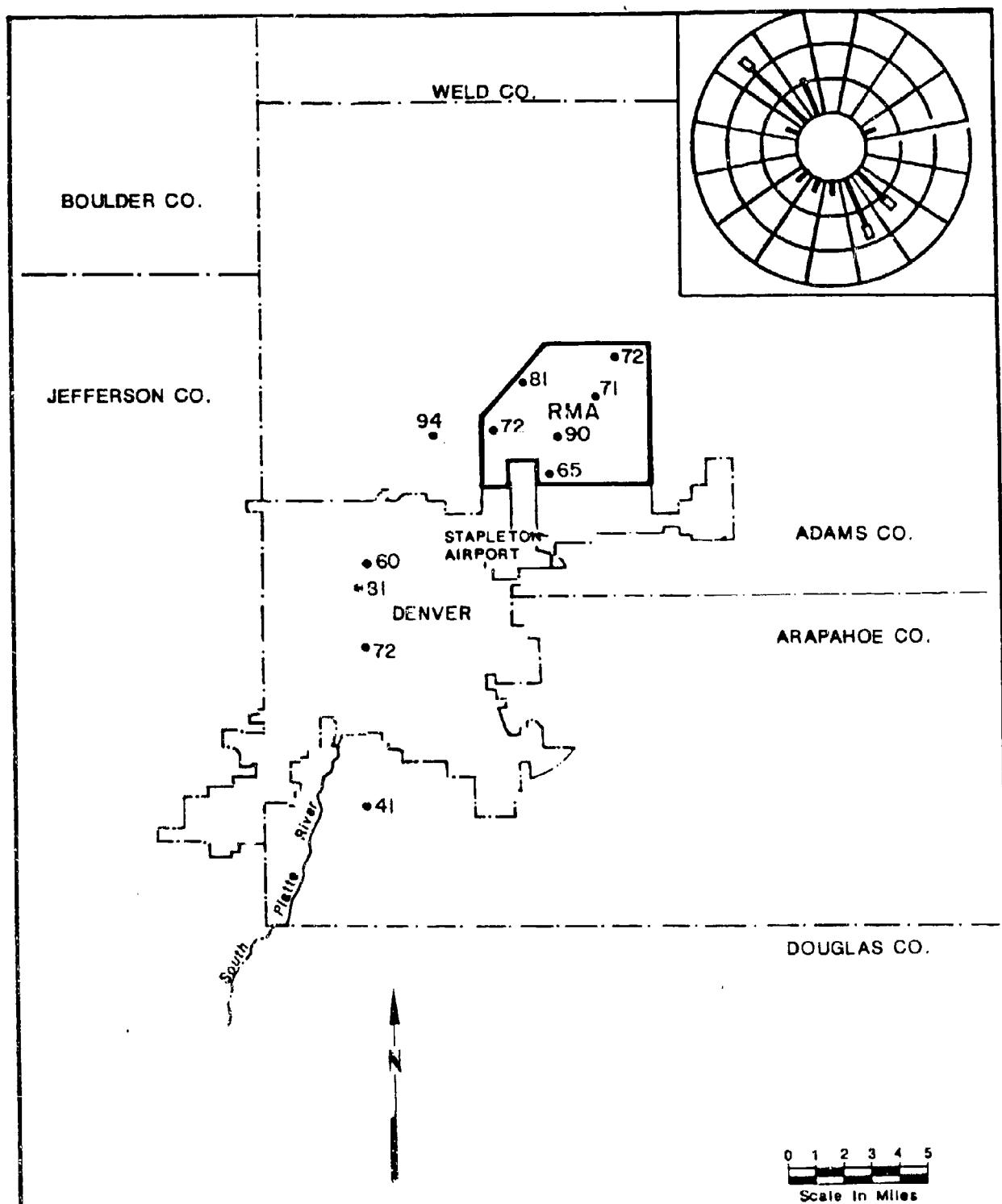
4.3.2 BASIN F PM-10 IMPACTS

4.3.2.1 CMP Data

Because of increased emphasis on PM-10 monitoring, a record of PM-10 levels during and after remediation has been maintained. Table 4.3-3 lists PM-10 concentrations for the various phases of the remediation and post-remediation periods. A summary of the results follows.

There were no violations of any PM-10 ambient standards during the Phase 1 period. The Phase 2, Stage 1 period (remedial landscaping/hauling) indicated occurrences of the highest PM-10 levels, but they were most likely attributed to the winter seasonal impacts over RMA from metropolitan Denver. The highest average concentration ($52 \mu\text{g}/\text{m}^3$) for the 2-month period (December 13, 1988, through February 15, 1989) occurred at AQ1 at the western RMA boundary. The highest 24-hour PM-10 concentration of $168 \mu\text{g}/\text{m}^3$ also occurred at AQ1; this was an exceedance of the 24-hour ambient standard of $150 \mu\text{g}/\text{m}^3$. As noted in the FY89 report, this occurred on February 9, 1989, when metropolitan Denver and all Arsenal stations received their highest PM-10 levels for several years. During the Phase 4 post-remedial period, PM-10 levels were consistently low across the Arsenal, ranging from an average value of $25 \mu\text{g}/\text{m}^3$ at AQ2 to $19 \mu\text{g}/\text{m}^3$ at AQ9. The cessation of remedial activity may also have had a very minor influence in decreasing PM-10 values.

Because the CMP did not measure PM-10 immediately adjacent to Basin F operations, it is difficult to identify the full impact of Basin F operations on PM-10 levels. It is likely that PM-10 monitoring at AQ10 and AQ11, where very high TSP levels were monitored during the Phase 1 and Phase 2 periods (see Table 4.2-3), would also have resulted in higher PM-10 levels. A study conducted over



Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
R.L. Stuller & Associates

Figure 4.3-1
PM-10 Results for 9/14/90 ($\mu\text{g}/\text{m}^3$)
CMP AR FY90

Table 4.3-3 Concentrations of Respirable Particulates of Less than 10 Microns (PM-10) for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)

Month	AQ1	AQ2	AQ3	AQ5C	AQ5D	AQ9	AQ10
Summary of Arithmetic Mean Concentrations *							
PHASE 1							
March		27		26		36	
April		23		19		20	
May		19		14		15	
June		24		17		15	
July		30		23		22	
August		37		25	36	25	
September		33		20	20	22	
October	38	37	34	25	27	25	
November	32	26	20	21	23	18	
December	57	50	42	36	39	37	
PHASE 2 - STAGE 1							
December	36	29	24	25	28	20	
January	44	30	24	28	30	19	
February	80	53	47	55	61	47	
PHASE 2 - STAGE 2							
February	27	18	16	18	19	14	
March	39	25	22	27	29	21	
April	25	20	18	17	18	15	
May	25	19	16	15	15	14	
PHASE 3							
May	29	26	21	22	24	19	
June	21	20	18	19	18	18	
July	26	38	25	23	21	25	
August	17	22	17	17	15	17	
September	27	26	26	23	23	22	
PHASE 4							
October	39	40	32	29	29	28	
November	28	25	22	20	20	18	
December	20	22	15	20	20	15	
January	22	21	16	24	24	12	
February	22	32	24	26	26	23	
March	15	14	12	13	11	12	
April	17	17	14	18	14	13	
May	18	17	14	15	15	16	
June	23	28	21	22	21	22	
July	17	20	20	12	15	15	
August	26	28	22	22	21	21	
September	29	31	26	25	25	26	36

Table 4.3-3 Concentrations of Respirable Particulates of Less than 10 Microns (PM-10) for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Month	AQ1	AQ2	AQ3	AQ5C	AQ5D	AQ9	AQ10
SUMMARY							
Pre-Rem		36		33		18	
Phase 1	39	30	30	22	27	22	
Phase 2-1	52	36	30	35	39	27	
Phase 2-2	31	22	19	21	22	17	
Phase 3	24	26	21	21	20	20	
Phase 4	23	25	20	21	20	19	36
Summary of 24-Hour Maximum Concentrations **							
PHASE 1							
March		46		34		36	
April		43		39		39	
May		27		19		18	
June		41		19		18	
July		42		35		30	
August		67		39	42	42	
September		61		37	33	41	
October	47	47	46	36	41	35	
November	48	39	34	34	37	32	
December	77	72	60	47	51	51	
PHASE 2 - STAGE 1							
December	51	44	40	43	45	34	
January	95	65	50	71	74	44	
February	168	105	94	116	128	94	
PHASE 2 - STAGE 2							
February	38	23	19	25	27	19	
March	56	33	30	37	41	27	
April	38	29	29	25	26	22	
May	25	19	16	15	15	14	
PHASE 3							
May	34	29	24	26	28	21	
June	33	34	31	28	26	34	
July	35	46	35	33	31	36	
August	20	27	19	19	18	19	
September	39	45	37	29	28	32	

Table 4.3-3 Concentrations of Respirable Particulates of Less than 10 Microns (PM-10) for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

Month	AQ1	AQ2	AQ3	AQ5C	AQ5D	AQ9	AQ10
PHASE 4							
October	67	66	56	50	51	43	
November	43	35	35	30	30	29	
December	25	30	20	26	25	17	
January	44	33	24	66	66	22	
February	28	75	59	60	60	57	
March	22	27	15	18	17	16	
April	32	34	25	28	29	25	
May	25	24	20	24	24	29	
June	37	44	33	30	30	37	
July	25	29	24	18	21	26	
August	37	42	34	33	33	30	
September	72	81	72	65	67	71	90
SUMMARY							
Pre-Rem		94		90		36	
Phase 1	77	72	60	47	51	51	
Phase 2-1	168	105	94	116	128	94	
Phase 2-2	56	33	30	37	41	27	
Phase 3	39	46	37	33	31	36	
Phase 4	72	81	72	66	67	71	90

* Annual arithmetic mean standard is $50 \mu\text{g}/\text{m}^3$.

** Maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$.

Note: Pre-Rem refers to data collected during the Air Remedial Investigation (Environmental Science & Engineering, Inc. 1988).

Phase 1 is from March 22 to December 12, 1988.

Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.

Phase 2, Stage 2 is from February 16 to May 5, 1989.

Phase 3 is from May 6 to September 30, 1989.

Phase 4 is from October 1, 1989 to September 30, 1990 (FY90).

AQ10 was installed in the northwest quarter of Section 1 on September 5, 1990.

the 31-month CMP monitoring period indicated that PM-10 levels ranged from 36 to 63 percent of TSP levels. Figures 4.3-2, 4.3-3, and 4.3-4 compare sequential TSP and PM-10 concentrations for AQ2, AQ5, and AQ9 during FY90. The PM-10 to TSP ratios are 0.45, 0.56, and 0.60 for AQ2, AQ5, and AQ9, respectively. This infers that stations immediately downwind from Basin F cleanup activities (i.e., AQ10 and AQ11) would have measured higher PM-10 levels corresponding to the higher TSP levels. Station AQ2 has consistently measured the lowest ratios of PM-10 to TSP concentrations; 36 percent in 1988, 43 percent in 1989, and 45 percent in 1990. Because of the proximity of AQ2 to the remedial area, it received more direct impacts from Basin F. Therefore, the lower PM-10 to TSP ratios at AQ2 suggested the premise (in the FY89 Assessment Report) that remedial impacts were less for smaller particulates than for TSP. However, AQ2 again had the lowest ratio during FY90, when Basin F remedial impacts were minimal or nonexistent. A possible explanation for the lower ratio would be that dust from Commerce City traffic impacts AQ2 and contains a higher percentage of heavier particles, resulting in a lower fraction of PM-10 within TSP.

In addition to source influences, seasonal and climatological conditions affected PM-10 monitoring results, as well. Table 4.3-4 shows seasonal PM-10 data averaged over the entire CMP. The highest average concentrations occurred in the fall and winter, coinciding with inversion or "brown cloud" conditions over metropolitan Denver. Considerable variability exists between seasonal maximum levels, depending on source influences, seasonal and climatological influences, and unique meteorological events. Table 4.3-5 shows seasonal PM-10 results for 10 consecutive quarters of the CMP from the spring of 1988 to the summer of 1990. Relatively low PM-10 concentrations were measured during the winter of FY90, possibly due to the lack of winter inversion impacts from metropolitan Denver. Higher average PM-10 concentrations, on the other hand, were experienced during the summer of FY90 as a result of the unique meteorological conditions that occurred on September 14, 1990 (previously discussed in Section 4.2.1).

It is difficult to generalize the principal cause of PM-10 impacts at RMA when using only a 3-year database. Nevertheless, higher average PM-10 levels during the fall and winter periods are consistent with the greater number of inversion and "brown cloud" episodes that occurred in metropolitan Denver during those months. It appears that PM-10 concentrations at the CMP monitoring stations were not significantly impacted by remediation, except immediately adjacent and downwind of construction activities. Levels of PM-10 data collected at RMA are comparable to levels reported in rural areas of Colorado (CDH, 1989).

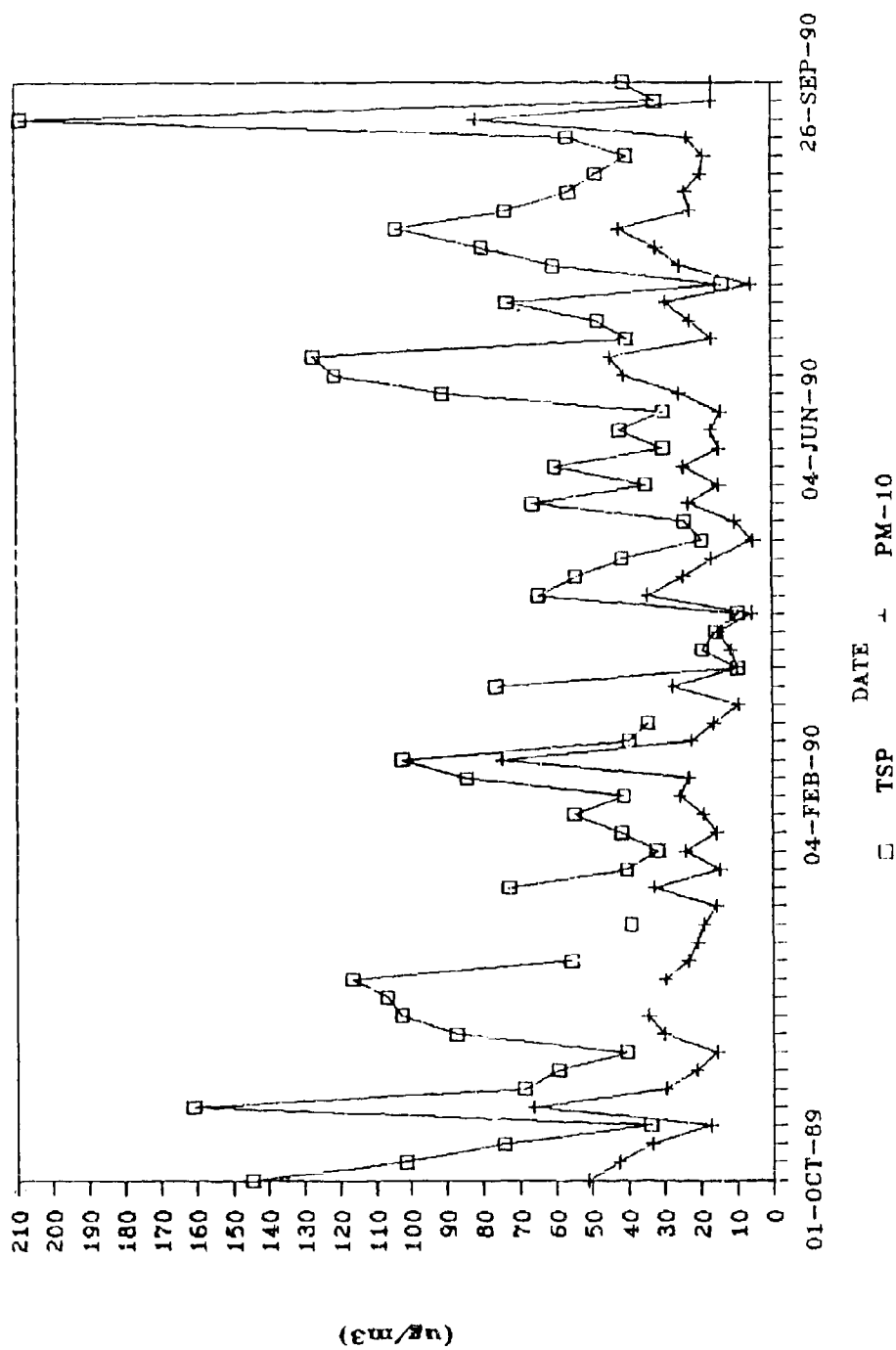


Figure 4.3-2
 Comparison of TSP and
 PM-10 at AQ2
 CMP AR FY90

Prepared for :
 U.S. Army Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by :
 R.L. Stollar & Associates, Inc.
 Ebaco Services, Inc.

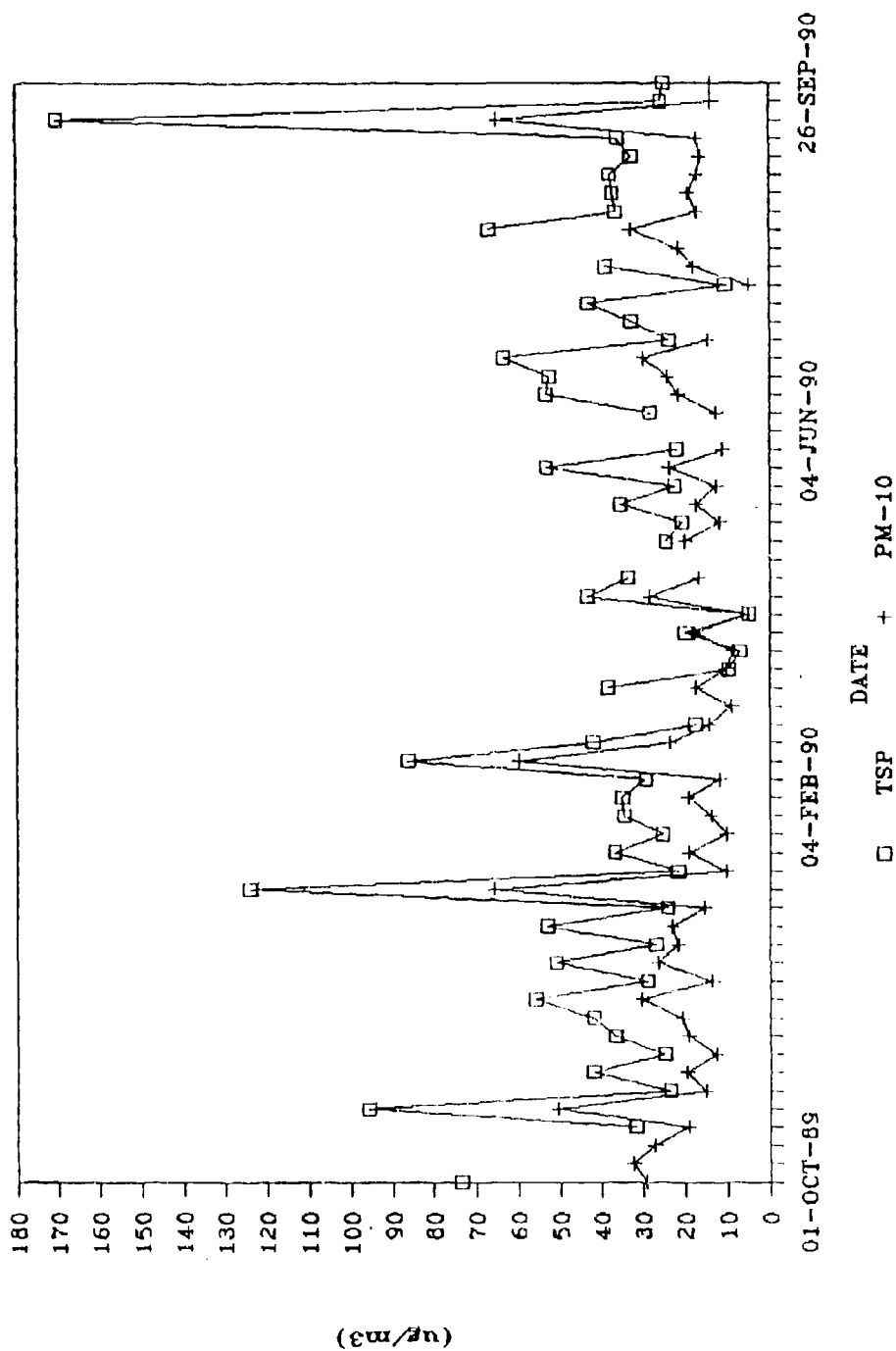
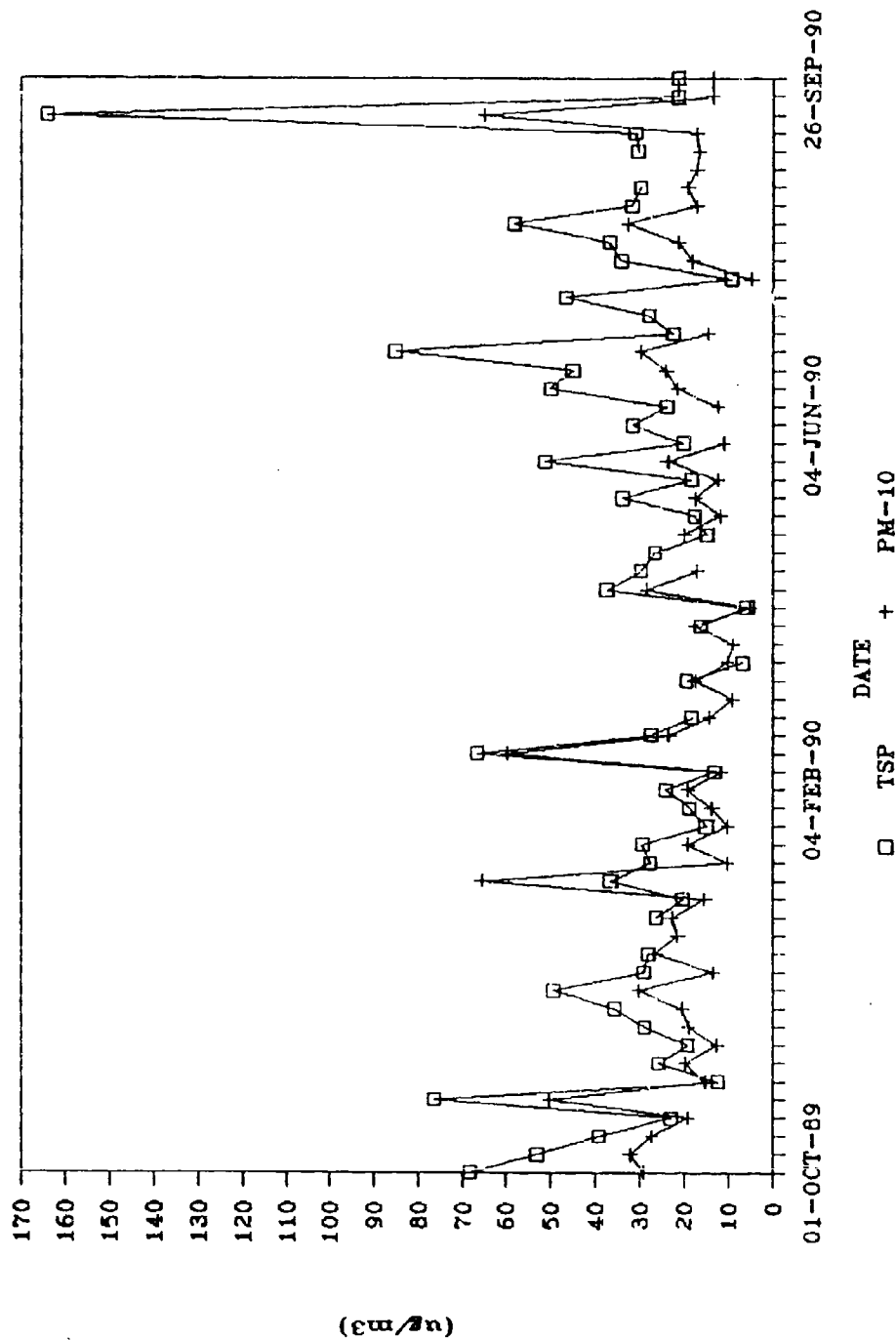


Figure 4.3-3
Comparison of TSP and
PM-10 at AQ5
CMP AR FY90

Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 4.3-4

Comparison of TSP and
PM-10 at AQ9

CMP AR FY90

Table 4.3-4 Combined Seasonal PM-10 Concentrations (in $\mu\text{g}/\text{m}^3$)

	Fall	Winter	Spring	Summer
AVERAGE				
AQ1B	34	36	21	24
AQ2B	33	28	20	30
AQ3B	27	23	16	23
AQ5C	24	27	16	21
AQ5D	26	29	17	21
AQ9B	23	22	16	22
AQ10B				36
SEASONAL AVERAGE	28	27	18	25
24-HOUR MAXIMUM				
AQ1B	77	168	38	72
AQ2B	72	105	46	81
AQ3B	60	94	29	72
AQ5C	50	116	39	65
AQ5D	51	128	29	67
AQ9B	51	94	39	71
AQ10B				90
SEASONAL MAXIMUM	77	168	46	90

Table 4.3-5 Seasonal PM-10 Concentrations by Site (in $\mu\text{g}/\text{m}^3$)

	AVERAGE							
	FY88				FY89			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
AQ1B			39	48	25	23	31	21
AQ2B	23	33	34	33	20	29	32	23
AQ3B			28	28	18	23	25	17
AQ5C	16	21	25	33	18	21	24	21
AQ5D		22	27	36	19	20	24	21
AQ9B	17	22	23	26	15	22	23	17
AQ10B								15
								36

	24-HOUR MAXIMUM							
	FY88				FY89			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
AQ1B			77	168	38	39	67	44
AQ2B	45	67	72	105	29	46	66	75
AQ3B			60	94	29	37	56	59
AQ5C	39	39	47	116	26	33	50	66
AQ5D		42	51	128	28	31	51	66
AQ9B	39	42	51	94	22	36	43	57
AQ10B								29
								90

4.3.2.2 Basin F Data

PM-10 was not measured in the immediate vicinity of Basin F during the Basin F Interim Remedial Monitoring Program. However, because of the increased emphasis placed on PM-10, monitoring of this criteria pollutant was initiated during the IRA-F follow-on monitoring program (Phases 3 and 4) to determine if any residual or post-remedial PM-10 impacts resulted from the Basin F remediation activities. The program consisted of monitoring every 12 days at FC1, downwind from Basin F and at FC3, upwind from Basin F. Results are shown in Table 4.3-6. Twenty-four hour sequential data are provided in Appendix M.

During the Phase 4 period, FC1 measured an average concentration of $24 \mu\text{g}/\text{m}^3$, while FC3 measured an average concentration of $23 \mu\text{g}/\text{m}^3$. The results of both monitoring stations were almost identical to other RMA interior monitoring sites, suggesting little or no post-remedial PM-10 impacts from the Basin F operations over the annual period.

The maximum 24-hour PM-10 concentrations were $102 \mu\text{g}/\text{m}^3$ and $88 \mu\text{g}/\text{m}^3$, respectively, at FC1 and FC3. These higher values again occurred on the "limited mixing" day of September 14, 1990, and were greater than the maximum values that were reported at the CMP monitoring stations for that day, which ranged from 66 to $81 \mu\text{g}/\text{m}^3$. This could be a reflection of either impacts from residual dust off Basin F or impacts from local remediation activity during the period of monitoring. For the most part, results from the IRA-F stations and the CMP interior stations were comparable during all of FY90, suggesting that any particulate impacts off the remediated Basin F were small.

4.3.2.3 Combined Basin F and CMP Data Analysis

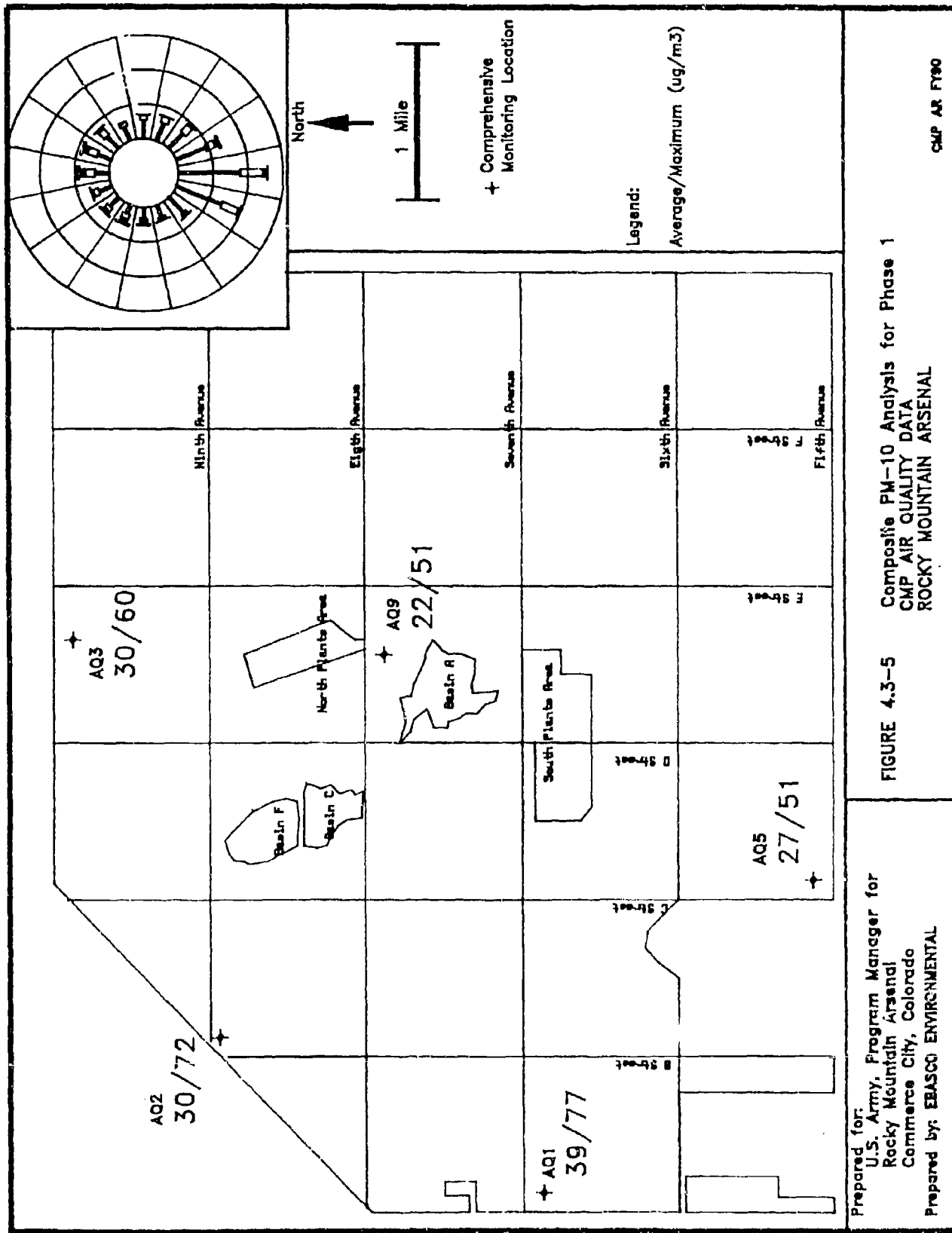
Individual CMP and Basin F PM-10 monitoring data for the designated phases of the Basin F remedial programs assessment have been shown in Tables 4.3-3 and 4.3-6. Figures 4.3-5 and 4.3-6 depict annual average and 24-hour maximum PM-10 values for Phases 1 and 4 (remedial and post-remedial periods). The wind roses reflecting transport of particles from a potential Basin F source are also shown on these figures. As noted from the previous discussions, these data show no apparent impact from the Basin F operation either during or after remedial activities. One possible exception is the high maximum 24-hour PM-10 concentrations that occurred at stations surrounding Basin F on September 14, 1990; however, this was an anomalous event. On the contrary, TSP mean levels were very evenly distributed across the Arsenal; the higher mean value at mobile station, AQ10, reflects a 4-week monitoring period under the influence of construction activity.

Table 4.3-6 Concentrations of Respirable Particulates of Less Than 10 Microns for Phases 3 and 4 at IRA-F Sites (in $\mu\text{g}/\text{m}^3$)

Month	FC1	FC3
Summary of Arithmetic Mean Concentrations*		
Phase 3 (5/5/89 - 9/30/89)		
June	18	16
July	35	26
August	18	18
September	21	23
Overall	23	22
Phase 4 (10/1/89 - 9/30/90)		
October	38	34
November	22	17
December	15	15
January	16	17
February	15	12
March	14	16
April	21	20
May	13	12
June	24	19
July	23	22
August	32	30
September	49	44
Overall	24	23
Summary of 24-Hour Maximum Concentrations **		
Phase 3 (5/5/89 - 9/30/89)		
June	18	16
July	35	36
August	18	18
September	27	31
Overall	35	36
Phase 4 (10/1/89 - 9/30/90)		
October	54	49
November	31	17
December	15	15
January	23	22
February	17	16
March	20	16
April	27	25
May	14	14
June	32	24
July	27	29
August	39	38
September	102	88
Overall	102	88

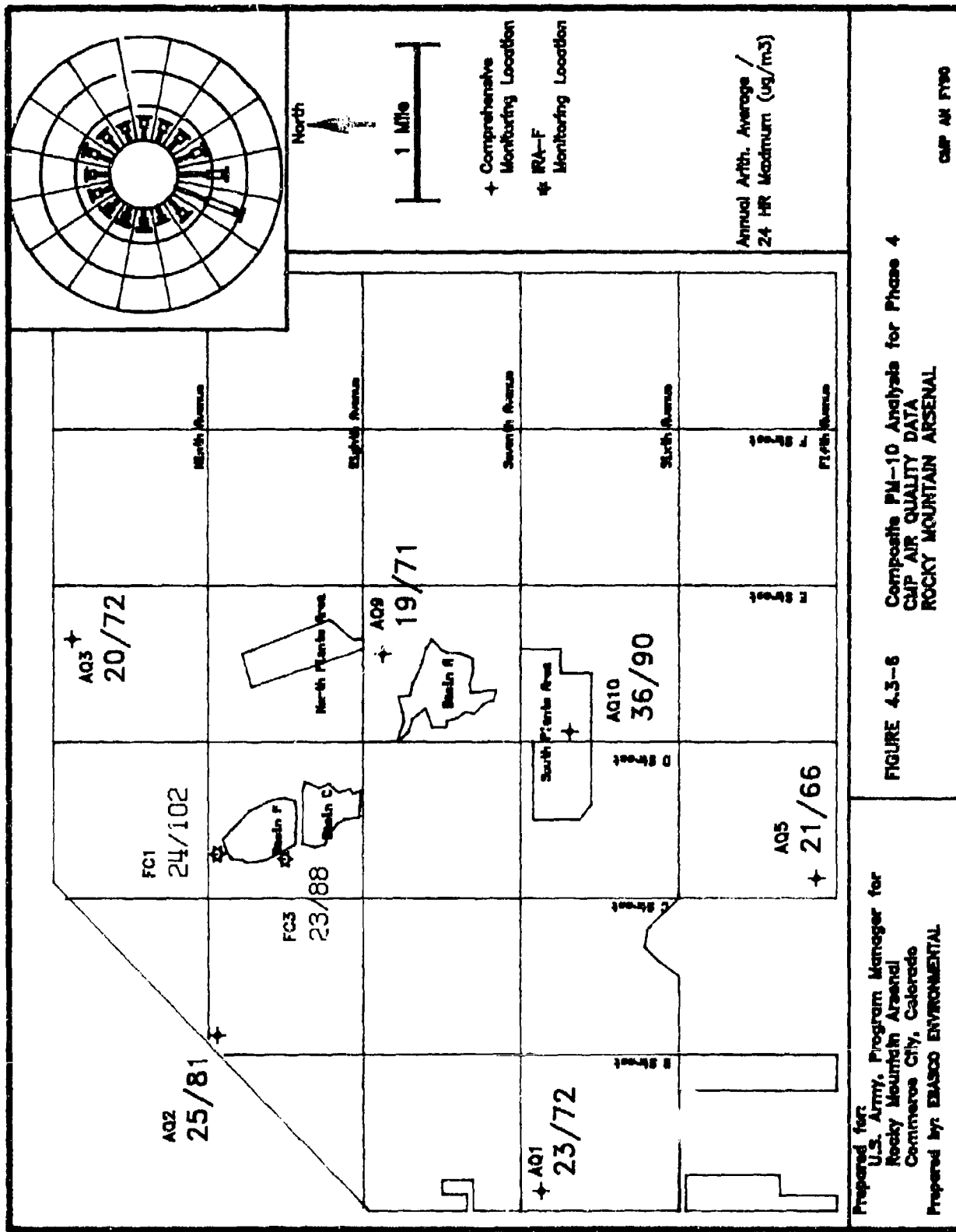
* Annual arithmetic mean standard is $50 \mu\text{g}/\text{m}^3$.

** Maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$.



Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: EBASCO ENVIRONMENTAL

FIGURE 4.3-5 Composite PM-10 Analysis for Phase 1
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL



Because PM-10 data were not collected immediately adjacent to Basin F during remedial activities, it cannot be concluded from these data that no PM-10 impacts resulted during the remedial program. Some elevated PM-10 levels were likely experienced in conjunction with high TSP levels that were occasionally measured. Data illustrated on Figures 4.3-5 and 4.3-6 during Phase 1 and Phase 4, however, suggest that any PM-10 impacts from Basin F operations were highly localized and did not spread to the RMA boundaries.

4.3.3 METROPOLITAN DENVER PM-10 DATA

As in the case of TSP, PM-10 concentrations were higher in metropolitan Denver than they were at RMA. The distribution of PM-10 data across metropolitan Denver and the Arsenal suggest that there was an influx of PM-10 into the Arsenal from the Denver area. PM-10 annual arithmetic mean and 24-hour maximum concentrations for Denver throughout the CMP including FY90 are shown in Table 4.3-7.

During the Phase 1 remediation period, PM-10 levels were generally uniform across both the metropolitan area and the Arsenal, with the highest average concentration of $40 \mu\text{g}/\text{m}^3$ reported at Adams City. There was no evidence of high PM-10 levels at the Arsenal interior, although PM-10 monitoring was not conducted immediately adjacent to Basin F.

During the Phase 2 (Stage 1) winter period, downtown Denver experienced a maximum average PM-10 level of $72 \mu\text{g}/\text{m}^3$ and a maximum 24-hour value of $154 \mu\text{g}/\text{m}^3$, while Adams City reached an average value of $73 \mu\text{g}/\text{m}^3$ and a maximum value of $145 \mu\text{g}/\text{m}^3$. As noted previously, several intense winter inversion episodes contributed to these results. During this period, the Arsenal area also measured high PM-10 levels on several days with maximum concentrations at the western and southern boundaries. Interior Arsenal sites indicated lower PM-10 concentrations, apparently less influenced by dispersion impacts from the metropolitan area.

During the Phase 2 (Stage 2), Phase 3, and Phase 4 periods, metropolitan Denver PM-10 levels decreased significantly, although the highest concentrations remained at downtown Denver and Adams City (in the direction of the prevailing wind flow). Figure 4.3-7 shows the distribution of PM-10 annual average values across metropolitan Denver and the Arsenal for the FY90 period. RMA values were again slightly higher at the western and southern boundaries; interior Arsenal stations reported their lowest PM-10 levels for the 31-month monitoring period during Phases 3 and 4, with one exception. The monitoring station installed at AQ10b in September, 1990 measured higher

Table 4.3-7 Denver Metropolitan Area Respirable Particulates of Less than 10 Microns (PM-10) (in $\mu\text{g}/\text{m}^3$)

Station	Phase 1	Phase 2-1	Phase 2-2	Phase 3	Phase 4 (FY90)
ARITHMETIC MEANS					
Adams City	40.5	72.8	27.2	31.2	32.1
8101 Ralston	27.2	36.0	27.2	34.8	**
1633 Florence	26.7	31.2	26.3	26.0	24.1
414 14th Street	30.6	71.7*	39.3*	32.2	31.1
CAMP/2105 Broadway	28.7	45.1	37.2	27.4	27.3
1050 S. Broadway	31.2	49.7*	35.2	29.7	32.1
4857 S. Broadway	23.1	39.9	27.4	23.6	22.0
24-HOUR MAXIMUM VALUES					
Adams City	103.0	145.0	36.0	50.0	94.0
8101 Ralston	56.0	57.0	59.0	78.0	**
1633 Florence	94.0	77.0	56.0	49.0	84.0
414 14th Street	66.0	123.0	59.0	54.0	118.0
CAMP/2105 Broadway	123.0	154.0	62.0	45.0	82.0
1050 S. Broadway	68.0	64.0	57.0	51.0	118.0
4857 S. Broadway	48.0	103.0	44.0	39.0	49.0

* Incomplete data set.

** Samples are no longer collected at this station.

Annual Arithmetic mean standard is $50 \mu\text{g}/\text{m}^3$.
Maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$.

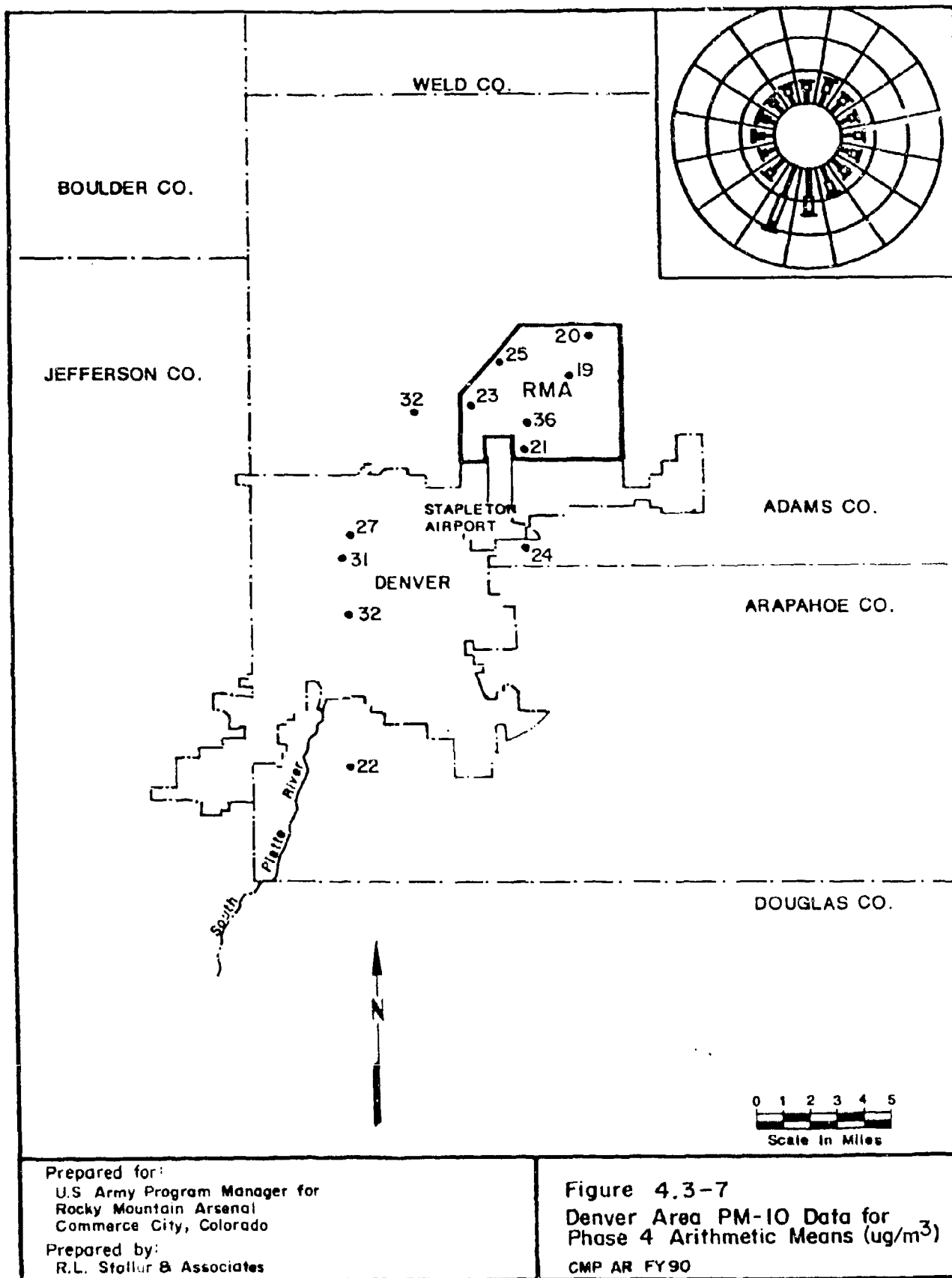
Phase 1 is from March 22 to December 12, 1988.

Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.

Phase 2, Stage 2 is from February 16 to May 5, 1989.

Phase 3 is from May 6 to September 30, 1989.

Phase 4 is from October 1, 1989 through September 30, 1990.



average PM-10 concentrations due to the shorter monitoring period and its proximity to South Plants subdrain activity.

4.3.4 SUMMARY OF PM-10 ANALYSIS

It would appear that strong gusty winds were conducive to higher PM-10 values at RMA, but at a much lesser extent than for TSP (at a ratio of 40 to 60 percent). The highest PM-10 readings were observed during strong atmospheric inversion conditions over metropolitan Denver. There were no violations of the annual or 24-hour PM-10 standards during FY90 at RMA. As in the case of TSP, there were potentially two principal sources of PM-10 impacting RMA and its surroundings: (1) the influx of PM-10 emissions from metropolitan Denver, and (2) remediation activity sources at RMA, especially during high wind episodes. Unlike the TSP assessment, the data do not indicate a detectable increase in average PM-10 levels during the remedial activity. This may be the result of the lack of PM-10 monitoring stations immediately adjacent to remedial activities; however, it would appear that any PM-10 remediation-generated emissions were localized and fell off significantly with distance from the activity, producing negligible off-post impacts. A modification to the Technical Plan now provides for the placement of mobile PM-10 monitors upwind and downwind of remedial and construction activities.

4.4 METALS

A total of six metallic ions were analyzed from the TSP filters after the filters were weighed, including arsenic, cadmium, chromium, copper, lead and zinc. Mercury was measured using Hydrar tubes and analyzed using the Rathje and Marcero method (AIHA, May 1976).

4.4.1 METALS MONITORING STRATEGIES

There were basically two components of the CMP FY90 metals monitoring effort. The first component was routine monitoring which involved every 6th day sampling at two sites, as shown in Table 4.4-1.

Table 4.4-1 Summary of Routine Metals Sampling for FY90

Station	Number of Samples	Percent Recovery
AQ3	60	98
AQ5	58	95
AQ5C ¹	59	97
PROGRAM TOTAL	177	97

- 1 AQ5C is a collocated station. The intent and operation of collocated stations are discussed in Section 8.4, Quality Assurance. A collocated sampler at AQ5 was installed and operated throughout the routine program.

The second component involved "high event" monitoring during specified high wind episodes (i.e. as a minimum, winds in excess of 10 mph). Twelve high event episodes were conducted for the six metal ion components and also for mercury. Monitoring was conducted at various locations across the Arsenal depending upon meteorological conditions and selected source activities or special interests.

The CMP FY90 high event metals program included both direct mobilization episodes around Basin F, Basin A, the South Plants, Basin A Neck, and the South Plants subdrain area, and post-analysis episodes at strategically located monitoring sites across the Arsenal. In most cases, winds were in excess of 10 mph, and gusts were frequently in excess of 25 mph, thus meeting the wind speed criteria established for high event analysis. In several cases, however, post-analysis of high TSP levels provided the criteria for high event metals analyses. This approach provided a practical and cost-effective method of obtaining data for days with potentially high metals concentrations. Metals analyses were obtained from TSP sample filters that were strategically located at interior and perimeter Arsenal sites.

4.4.2 CMP FY90 METALS MONITORING RESULTS

Average and maximum concentrations for the full CMP metals monitoring program for arsenic, cadmium, chromium, copper, lead and zinc are shown in Table 4.4-2, with detailed data in

Table 4.4-2 Summary of CMP Metals Concentrations for FY90 (in $\mu\text{g}/\text{m}^3$)

	Cadmium	Chromium	Copper	Lead**	Zinc	Arsenic	Mercury
	AVERAGE VALUES **						
AQ1	0.001048	*	0.091059	0.018319	0.037940	0.000628	*
AQ2	0.002094	*	0.090792	0.033069	0.034711	0.001401	*
AQ3	0.000785	*	0.083162	0.011153	0.021963	0.000496	*
AQ4	0.001025	*	0.074714	0.010841	0.014798	*	*
AQ5	0.001265	0.004398	0.073003	0.015520	0.028181	0.000492	*
AQ6	*	*	0.083974	0.012811	0.020538	0.000610	*
AQ7	*	*	0.061191	0.019987	0.033924	0.000989	*
AQ8	*	*	0.036997	0.011536	0.014929	0.001731	*
AQ9	*	*	0.038945	0.011572	0.016328	0.000511	*
AQ10	*	*	0.073597	0.014415	0.026308	0.000568	*
AQ11	*	*	0.036535	0.011884	0.021087	0.000695	*
AQ12	*	*	0.066461	0.015257	0.024227	0.000663	*
AQ01	*	*	0.039972	*	0.013388	*	*
AQ02	*	*	0.061615	0.022189	0.013400	*	*
AQ23	*	*	0.069083	0.009500	0.027124	*	*
AQ26	0.000681	*	0.092234	0.012298	0.027238	0.000501	*
AQ31	*	*	0.024359	*	0.014793	0.000496	*
AQ35	*	*	0.012033	0.006397	0.009906	*	*
AQ36	*	*	0.056481	*	0.011724	0.002540	*

* All values below CRL

** Calendar quarter lead standard is $1.5 \mu\text{g}/\text{m}^3$. Criteria and guidelines for other metals are outlined in Table 4.4-8.

*** Averages and maximum values include results from high percent sampling.

Table 4.4-2 Summary of CMP Metals Concentrations for FY90 (in $\mu\text{g}/\text{m}^3$) (continued)

	Cadmium	Chromium	Copper	Lead**	Zinc	Arsenic	Mercury
24-HOUR MAXIMUM VALUES ***							
AQ1	0.003284	*	0.212262	0.032020	0.072344	0.002754	*
AQ2	0.004003	*	0.105696	0.034243	0.064570	0.002333	*
AQ3	0.001947	*	0.245029	0.035001	0.058961	0.001790	*
AQ4	0.002323	*	0.138765	0.014775	0.024909	*	*
AQ5	0.028149	0.015085	0.134883	0.062088	0.108591	0.001892	*
AQ6	*	*	0.184847	0.017478	0.048059	0.001517	*
AQ7	*	*	0.061890	0.026452	0.036551	0.001574	*
AQ8	*	*	0.063838	0.017998	0.025660	0.004142	*
AQ9	*	*	0.062693	0.019163	0.026018	0.001303	*
AQ10	*	*	0.095592	0.019700	0.039461	0.001262	*
AQ11	*	*	0.060755	0.019787	0.026763	0.001485	*
AQ12	*	*	0.067066	0.017010	0.025886	0.001134	*
AQ01	*	*	0.066933	*	0.023233	*	*
AQ02	*	*	0.096168	0.047685	0.024184	*	*
AQ23	*	*	0.096479	0.014291	0.035370	*	*
AQ26	0.001415	*	0.222301	0.014429	0.052352	0.001218	*
AQ31	*	*	0.024359	*	0.014793	0.000496	*
AQ25	*	*	0.012033	0.006397	0.009906	*	*
AQ36	*	*	0.144949	*	0.013793	0.004224	*

* All values below CRL

** Calendar quarter lead standard is $1.5 \mu\text{g}/\text{m}^3$. Criteria and guidelines for other metals are outlined in Table 4.4-8.

*** Averages and maximum values include results from high event sampling.

Appendix C. Stations AQ3, AQ5 and AQ5C cover the entire period in accord with the Technical Plan. All other CMP monitoring stations data including mobile sites comprise results of high event monitoring periods, which were 24-hour periods except for a 6-hour sampling event on May 11, 1990.

Results of the CMP FY90 metals monitoring program were generally comparable to past CMP results. Metals levels detected were very low to insignificant with respect to ambient standards and health criteria (to be discussed in Section 4.4.5). With several exceptions, metals levels were fairly consistent across the Arsenal and for the most part were representative of their proximity to the Denver urban environment. For example, the highest average concentrations for most metals occurred at AQ1 and AQ2 on the western and northwestern Arsenal boundaries. Exceptions occurred, however, on a day-to-day basis. Maximum average and 24-hour concentrations measured in FY90 for each metal component are discussed below.

The maximum average cadmium value was $0.0021 \mu\text{g}/\text{m}^3$ measured at AQ2 and the maximum 24-hour value was $0.0281 \mu\text{g}/\text{m}^3$ measured at AQ5.

Chromium was detected at only one CMP location during FY90. The maximum average value was $0.0044 \mu\text{g}/\text{m}^3$ at AQ5, while the maximum 24-hour value of $0.0151 \mu\text{g}/\text{m}^3$ was also measured at AQ5. In FY88, chromium was detected only at AQ3 and was detected at Stations AQ7 and AQ12 during FY89. There appears to be no specific pattern of chromium concentrations at Arsenal sites.

The highest average copper level, $0.0922 \mu\text{g}/\text{m}^3$ occurred in the Basin F area; the maximum 24-hour value of $0.2450 \mu\text{g}/\text{m}^3$ was measured at AQ3 at the northern Arsenal boundary. Copper concentrations at some other sites across RMA were only slightly less than these values. The highest CMP copper levels during FY88 and FY89 were also measured at AQ3.

The highest average lead value was $0.0331 \mu\text{g}/\text{m}^3$ at AQ2 at the northwest perimeter of the Arsenal. The 24-hour maximum lead value was $0.0621 \mu\text{g}/\text{m}^3$ at AQ5 along the southern RMA perimeter. This was consistent with previous CMP measurements. During FY88, the highest measured average lead value was $0.0270 \mu\text{g}/\text{m}^3$ and the 24-hour maximum value was $0.0576 \mu\text{g}/\text{m}^3$, both at AQ2 along the northwestern perimeter. The highest average lead value measured during FY89 was $0.0291 \mu\text{g}/\text{m}^3$, while the highest 24-hour value was $0.0984 \mu\text{g}/\text{m}^3$ at AQ5.

A maximum average zinc level of $0.0371 \mu\text{g}/\text{m}^3$ was measured at AQ1. A maximum 24-hour value of $0.1086 \mu\text{g}/\text{m}^3$ was measured at AQ5. During FY88, the highest zinc levels were measured at AQ1

and AQ2 at the western boundary. During FY89, zinc levels at these stations were next highest after AQ7, where one isolated 24-hour measurement of $0.2908 \mu\text{g}/\text{m}^3$ was recorded.

The maximum average arsenic level was $0.0005 \mu\text{g}/\text{m}^3$ and the maximum 24-hour concentration was $0.0042 \mu\text{g}/\text{m}^3$, both at a mobile site in Basin A. During FY88 and FY89, AQ8 which is close to Basin A also measured the highest arsenic levels under the CMP. It appears that there may be a low level source of arsenic in the vicinity of Basin A.

Mercury was not detected throughout the CMP FY90 Monitoring Program. The lower certified reporting limit for mercury is 0.089 ug. Mercury sampling was conducted during 12 separate high event episodes for a total of 117 samples. These samples were collected throughout the year and focussed on a variety of sources which might have acted as potential sources of mercury emissions.

4.4.3 ASSESSMENT OF BASIN F METALS IMPACTS

4.4.3.1 CMP Data

In order to fully evaluate remedial impacts from the Basin F cleanup operations, it is necessary to consider all CMP, Basin F Remedial Monitoring Program, and IRA-F data for the entire remedial and post-remedial periods. CMP FY90 metals results were discussed in the previous section. Table 4.4-3 incorporates CMP FY88, FY89, and FY90 data and stratifies results for each monitoring station for the Phase 1 and Phase 2 remediation periods and the Phase 3 and Phase 4 post-remedial periods. These data reflected no significant metals impacts from Basin F at CMP monitoring sites over the 31-month monitoring period. For each metal element analyzed, variations (at fixed and mobile monitoring stations) were small and likely reflected individual wind and TSP conditions as well as some seasonal differences. It should be noted, however, that Basin F program monitoring sites immediately adjacent to the intense remedial activity did, in fact, identify several metal elements (chromium, copper, zinc, and mercury) that reflected higher concentrations during the Basin F cleanup operations. These levels decreased during the post-remedial periods, as discussed in the following section. The lack of a significant remediation and post-remediation pattern at CMP sites, slightly further downstream than the Basin F monitoring sites, substantiates the premise that Basin F metals impacts were highly localized and decreased rapidly with distance from the remedial activities. It is also interesting that the CMP metals levels measured during the remediation phases (Phase 1 and Phase 2, Stage 1) that encompassed the Basin F remediation activity were comparable

Table 4.4-3 Summary of CMP Metals Concentrations by Phase (in $\mu\text{g}/\text{m}^3$)

	Cadmium	Chromium	Copper	Lead**	Zinc	Arsenic	Mercury
AVERAGE VALUES							
PHASE 1							
AQ1	0.000727	*	0.052996	0.026991	0.046046	0.000675	*
AQ2	0.000717	*	0.055301	0.027037	0.041856	0.000615	*
AQ3	0.000471	0.002680	0.108094	0.012940	0.025115	0.000472	*
AQ4	*	*	0.054367	0.010960	0.025140	0.000597	*
AQ5	0.001244	*	0.085670	0.019090	0.030828	0.000482	*
AQ6	0.000321	*	0.061958	0.012233	0.021960	0.000428	*
AQ7	0.000440	*	0.081590	0.017839	0.037150	0.000501	*
AQ8	0.000373	*	0.096483	0.012968	0.024437	0.001454	*
AQ9	0.000296	*	0.062143	0.011499	0.022326	0.000444	*
AQ10	*	*	0.043888	0.009889	0.045437	0.001196	*
AQ11	0.000722	*	0.098143	0.012011	0.027587	0.000535	*
AQ12	0.000286	*	0.077228	0.010950	0.018927	0.000508	*
PHASE 2 - STAGE 1							
AQ3	0.001207	*	0.086848	0.019109	0.025026	0.001007	*
AQ5	0.001326	*	0.089639	0.033968	0.042749	0.001026	*
PHASE 2 - STAGE 2							
AQ1	0.001247	*	0.070093	0.028559	0.047227	0.001289	*
AQ2	0.000787	*	0.065431	0.025759	0.049034	0.001609	*
AQ3	0.000320	*	0.081032	0.009143	0.018193	0.000633	*
AQ4	0.000403	*	0.053458	0.012827	0.022954	0.000709	*
AQ5	0.000485	*	0.080511	0.015271	0.027584	0.000719	*
AQ6	0.000847	*	0.073725	0.016783	0.030312	0.000834	*
AQ7	0.001417	0.004364	0.047011	0.022008	0.146214	0.000833	*
AQ8	0.000841	*	0.063551	0.012492	0.028814	0.002445	*

Table 4.4-3 Summary of CMP Metals Concentrations by Phase (in $\mu\text{g}/\text{m}^3$) (continued)

	Cadmium	Chromium	Copper	Lead**	Zinc	Arsenic	Mercury
AVERAGE VALUES (continued)							
PHASE 2 - STAGE 2 (continued)							
AQ9	0.000769	*	0.074765	0.013648	0.026143	0.000918	*
AQ10	0.000614	*	0.073663	0.011971	0.028115	0.000719	*
AQ11	0.000394	*	0.033639	0.011119	0.030854	0.000811	*
AQ12	*	0.004098	0.050616	0.011193	0.030488	0.001062	*
PHASE 3							
AQ1	*	*	0.091311	0.015979	0.030726	0.000388	*
AQ2	0.001037	*	0.084262	0.013020	0.035341	0.000445	*
AQ3	0.000346	*	0.116425	0.011695	0.018882	0.000361	*
AQ4	*	*	0.075989	0.006749	0.018877	0.000298	*
AQ5	0.000280	*	0.069275	0.013683	0.022226	0.000358	*
AQ6	*	*	0.086772	0.007364	0.018138	0.000242	*
AQ7	*	*	0.042132	0.057267	0.022382	*	*
AQ8	*	*	0.038484	0.009581	0.020646	0.000936	*
AQ9	*	*	0.054277	0.013668	0.021256	*	*
AQ10	*	*	0.093414	0.007323	0.031296	0.000323	*
AQ11	*	*	0.103172	0.006696	0.036533	0.000310	*
AQ12	*	*	0.126681	0.008199	0.023400	0.000458	*
BF3	*	*	0.048486	0.020637	0.039584	*	*
BF6	*	*	0.058762	0.016919	0.033861	*	*
PHASE 4							
AQ1	0.001048	*	0.091059	0.018319	0.037940	0.000628	*
AQ2	0.002094	*	0.090792	0.033069	0.034711	0.001401	*
AQ3	0.000785	*	0.083162	0.011153	0.021963	0.000496	*
AQ4	0.001025	*	0.074714	0.010841	0.014798	*	*
AQ5	0.001265	0.004398	0.073003	0.015520	0.028181	0.000492	*

Table 4.4-3 Summary of CMP Metals Concentrations by Phase (in $\mu\text{g}/\text{m}^3$) (continued)

	Cadmium	Chromium	Copper	Lead**	Zinc	Arsenic	Mercury
PHASE 4 (continued)							
AVERAGE VALUES (continued)							
AQ6	*	*	0.089974	0.012811	0.020538	0.000610	*
AQ7	*	*	0.061191	0.019978	0.033924	0.000989	*
AQ8	*	*	0.036997	0.011536	0.014929	0.001731	*
AQ9	*	*	0.038945	0.011572	0.016328	0.000511	*
AQ10	*	*	0.073597	0.014415	0.026308	0.000568	*
AQ11	*	*	0.036535	0.011884	0.021087	0.000695	*
AQ12	*	*	0.066461	0.015257	0.024227	0.000663	*
AQ01	*	*	0.039972	*	0.013388	*	*
AQ02	*	*	0.061615	0.022189	0.013400	*	*
AQ23	*	*	0.069083	0.009500	0.027124	*	*
AQ26	0.000681	*	0.092234	0.012298	0.027238	0.000501	*
AQ31	*	*	0.024359	*	0.014793	0.000496	*
AQ35	*	*	0.012033	0.006397	0.009906	*	*
AQ36	*	*	0.056481	*	0.011724	0.002540	*
24-HOUR MAXIMUM VALUES							
PHASE 1							
AQ1	0.001494	*	0.107176	0.043839	0.076761	0.001743	*
AQ2	0.001526	*	0.107616	0.057614	0.062668	0.001664	*
AQ3	0.001913	0.009636	0.287323	0.042410	0.069498	0.001872	*
AQ4	*	*	0.094612	0.013698	0.026226	0.000641	*
AQ5	0.025265	*	0.155868	0.055761	0.084038	0.001826	*
AQ6	0.000533	*	0.132744	0.017265	0.030751	0.000958	*
AQ7	0.001093	*	0.193226	0.022883	0.053563	0.001441	*
AQ8	0.000832	*	0.193701	0.018730	0.034002	0.004122	*
AQ9	0.000746	*	0.160112	0.016663	0.046030	0.000926	*

Table 4.4-3 Summary of CMP Metals Concentrations by Phase (in $\mu\text{g}/\text{m}^3$) (continued)

	Cadmium	Chromium	Copper	Lead**	Zinc	Arsenic	Mercury
24-HOUR MAXIMUM VALUES (continued)							
PHASE 1 (continued)							
AQ10	*	*	0.071980	0.010580	0.063189	0.001816	*
AQ11	0.004098	*	0.156818	0.017014	0.065236	0.001154	*
AQ12	0.000697	*	0.124163	0.016409	0.036511	0.001201	*
PHASE 2 - STAGE 1							
AQ3	0.005735	*	0.215672	0.058837	0.070024	0.004237	*
AQ5	0.005276	*	0.192351	0.098442	0.115958	0.004551	*
PHASE 2 - STAGE 2							
AQ1	0.004258	*	0.216952	0.060260	0.094310	0.004875	*
AQ2	0.002686	*	0.088272	0.045431	0.069639	0.005823	*
AQ3	0.001115	*	0.167273	0.028106	0.039742	0.003090	*
AQ4	0.001062	*	0.104382	0.034763	0.049773	0.002623	*
AQ5	0.002923	*	0.123754	0.034095	0.054662	0.003246	*
AQ6	0.001653	*	0.136534	0.027104	0.048587	0.002433	*
AQ7	0.001970	0.010206	0.107229	0.036759	0.290812	0.002373	*
AQ8	0.001842	*	0.118427	0.029376	0.059744	0.007368	*
AQ9	0.001245	*	0.130539	0.031944	0.054549	0.002713	*
AQ10	0.001884	*	0.173848	0.035278	0.068872	0.002615	*
AQ11	0.001191	*	0.098640	0.029214	0.070754	0.002699	*
AQ12	*	0.012863	0.105145	0.030376	0.078852	0.004283	*
PHASE 3							
AQ1	*	*	0.167180	0.025478	0.039875	0.000574	*
AQ2	0.003580	*	0.175219	0.015281	0.046939	0.000599	*
AQ3	0.001918	*	0.218258	0.049808	0.031711	0.000882	*

Table 4.4-3 Summary of CMP Metals Concentrations by Phase (in $\mu\text{g}/\text{m}^3$) (continued)

	Cadmium	Chromium	Copper	Lead**	Zinc	Arsenic	Mercury
24-HOUR MAXIMUM VALUES (continued)							
PHASE 3 (continued)							
AQ4	*	*	0.104196	0.015888	0.022481	0.000532	*
AQ5	3.001221	*	0.184251	0.033756	0.039404	0.000812	*
AQ6	*	*	0.109768	0.010271	0.018864	0.000426	*
AQ7	*	*	0.042132	0.057267	0.022382	*	*
AQ8	*	*	0.052188	0.020263	0.025110	0.001434	*
AQ9	*	*	0.083477	0.021998	0.021751	*	*
AQ10	*	*	0.126874	0.009303	0.048506	0.000597	*
AQ11	*	*	0.171482	0.007696	0.059436	0.000563	*
AQ12	*	*	0.184211	0.017406	0.028141	0.000626	*
BF3	*	*	0.048486	0.020637	0.039584	*	*
BF6	*	*	0.058762	0.016919	0.033861	*	*
PHASE 4							
AQ1	0.003284	*	0.212262	0.032020	0.072344	0.002754	*
AQ2	0.004003	*	0.105696	0.034243	0.064570	0.002333	*
AQ3	0.001947	*	0.245029	0.035001	0.058961	0.001790	*
AQ4	0.002323	*	0.138765	0.014775	0.024909	*	*
AQ5	0.028149	0.015085	0.134883	0.062088	0.108591	0.001892	*
AQ6	*	*	0.184847	0.017478	0.048059	0.001517	*
AQ7	*	*	0.061890	0.026452	0.036551	0.001574	*
AQ8	*	*	0.063838	0.017998	0.025660	0.004142	*
AQ9	*	*	0.062693	0.019163	0.026018	0.001303	*
AQ10	*	*	0.095592	0.019700	0.039461	0.001262	*
AQ11	*	*	0.060755	0.019787	0.026763	0.001485	*
AQ12	*	*	0.067066	0.017010	0.025886	0.001134	*
AQ01	*	*	0.066933	*	0.023233	*	*
AQ02	*	*	0.096168	0.047685	0.024184	*	*

Table 4.4-3 Summary of CMP Metals Concentrations by Phase (in $\mu\text{g}/\text{m}^3$) (continued)

	Cadmium	Chromium	Copper	Lead**	Zinc	Arsenic	Mercury
24-HOUR MAXIMUM VALUES (continued)							
PHASE 4 (continued)							
AQ23	*	*	0.096479	0.014291	0.035370	*	*
AQ26	0.001415	*	0.222301	0.014429	0.052352	0.001218	*
AQ31	*	*	0.024359	*	0.014793	0.000496	*
AQ35	*	*	0.012033	0.006397	0.009906	*	*
AQ36	*	*	0.144949	*	0.013793	0.004224	*

* All values below CRL

** Calendar quarter lead standard is $1.5 \mu\text{g}/\text{m}^3$. Criteria and guidelines for other metals are outlined in Table 4.4-9.

to high event metals data collected under the 1986-1987 Remedial Investigation Program shown in Table 4.4-4 below.

Table 4.4-4 Metals Data Summary for 1986-1987 Remedial Investigation Program

Metals	Detection Limit ($\mu\text{g}/\text{m}^3$)	Range of Values Above Detection Limits ($\mu\text{g}/\text{m}^3$)	
		From TSP Filters ¹	From PM-10 Filters ²
As	0.003	0.005 - 0.012 (2)*	NHADL**
Cd	0.002	0.002 - 0.017 (21)	0.002 - 0.003 (4)
Cr	0.003	0.003 - 0.050 (19)	NHADL
Cu	0.016	0.026 - .912 (81)	0.019 - 0.029 (3)
Hg***	0.063	NHADL	NHADL
Pb	0.008	0.010 - 0.062 (66)	0.009 - 0.037 (6)
Zn	0.010	0.128 - 10.2 (11)	NHADL

Source: ESE, 1988.

- 1 Total number of TSP filters analyzed = 87.
- 2 Total number of PM-10 filters analyzed = 7.
- * Number of hits above detection limits.
- ** NHADL - No hits above detection limits.
- *** Hg collected on HopcaliteTM media.

4.4.3.2 Basin F Data

Table 4.4-5 shows average and maximum metals values for the Basin F Remedial Monitoring Program and for the IRA-F Monitoring Program for Phases 1 through 4 of the remediation activities and post-remediation periods. All Phase 1 data and Phase 2 (Stage 1 and Stage 2) data were obtained from the Basin F Remedial Monitoring Program and cover the period from March 22, 1988, through May 5, 1989. The Phase 3 and Phase 4 data were obtained from the IRA-F Monitoring Program and cover a period from May 6, 1989, through September 30, 1990. Sequential data for the IRA-F program are provided in Appendix N.

Figures 4.4-1 through 4.4-7 graphically depict maximum and average concentrations for each metal component. The data are also stratified by the remedial phase periods. The metals summaries and corresponding figures show that several metals components, in particular chromium, zinc and

Table 4.4-5 Summary of Basin F/IRA-F/RIFS Metals Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)

	CD	CR	CU	PB	ZN	AS	HG	NH3
AVERAGE VALUES								
PHASE 1 (3/22/88 - 12/12/88)								
BF1	0.0006	0.0128	0.1163	0.0148	0.0688	0.0008	1.6	
BF2	0.0008	0.0101	0.1516	0.0175	0.0727	0.0009	1.6	
BF2C	0.0005	0.0126	0.1539	0.0172	0.0951	0.0010	1.3	
BF3	0.0005	0.0176	0.0944	0.0138	0.0776	0.0007	1.5	
BF4	0.0006	0.0200	0.1258	0.0160	0.0779	0.0009	1.5	
BF5	0.0006	0.0026	0.0712	0.0144	0.0508	0.0012	1.2	284.1
BF6	0.0005	0.0032	0.0746	0.0146	0.0472	0.0008	1.4	280.9
BF7	0.0006	0.0023	0.0791	0.0140	0.0493	0.0007	1.4	ND
PHASE 2 - STAGE 1 (12/13/88 - 2/15/89)								
BF1	0.0009	0.0036	0.0569	0.0200	0.2243	0.0008	1.3	
BF2	0.0006	0.0037	0.0646	0.0220	0.0931	0.0011	1.2	
BF2C	0.0006	0.0045	0.0687	0.0215	0.1476	0.0013	ND	
BF3	0.0007	0.0026	0.0566	0.0181	0.1952	0.0009	1.2	
BF4	0.0007	0.0028	0.0578	0.0202	0.1494	0.0009	ND	
BF5	0.0006	0.0031	0.0522	0.0159	0.3260	0.0008	ND	ND
BF6	0.0006	0.0027	0.0679	0.0167	0.0524	0.0008	ND	ND
BF7	0.0005	0.0033	0.0684	0.0173	0.1915	0.0007	ND	ND
RIFS1	0.0016	ND	0.0762	0.0397	0.0539	0.0008	ND	ND
RIFS1D	0.0018	ND	0.0851	0.0405	0.0509	0.0011	ND	ND
RIFS2	0.0007	ND	0.0783	0.0248	0.0337	0.0008	ND	ND
PHASE 2 - STAGE 2 (2/16/89 - 5/5/89)								
BF1	0.0008	0.0026	0.0429	0.0134	0.1052	0.0007	ND	
BF2	0.0006	0.0031	0.0528	0.0148	0.0716	0.0008	ND	
BF2C	0.0005	0.0034	0.0817	0.0152	0.0730	0.0007	ND	
BF3	0.0006	0.0025	0.0546	0.0137	0.1203	0.0007	ND	
BF4	0.0006	0.0029	0.0533	0.0135	0.0430	0.0007	ND	
BF5	0.0023	0.0022	0.0377	0.0134	0.0832	ND	ND	ND
BF6	0.0004	0.0032	0.0445	0.0145	0.0403	0.0008	ND	ND
BF7	0.0006	0.0024	0.0701	0.0133	0.0814	ND	ND	ND
RIFS1	0.0008	0.0031	0.0999	0.0232	0.0413	0.0007	ND	ND
RIFS1D	0.0012	ND	0.1072	0.0231	0.1105	0.0005	ND	ND
RIFS2	0.0008	ND	0.0899	0.0218	0.0363	0.0009	ND	ND

Legend:

CD	Cadmium	ZN	Zinc
CR	Chromium	AS	Arsenic
CU	Copper	HG	Mercury
PB	Lead	NH3	Ammonia

Table 4.4-5 Summary of Basin F/IRA-F/RIFS Metals Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)(continued)

	CD	CR	CU	PB	ZN	AS	HG	NH3
AVERAGE VALUES								
PHASE 3 (5/6/89 - 9/30/89)								
FC1	0.0013	ND	0.1434	0.0255	0.0217	0.0005	ND	
FC2	0.0008	ND	0.0961	0.0152	0.0182	0.0003	ND	
FC2D	0.0007	ND	0.1366	0.0140	0.0195	0.0003	ND	
BF3/FC3	0.0007	ND	0.1081	0.0147	0.0204	0.0003	ND	
BF4/FC4	0.0007	ND	0.1095	0.0148	0.0196	0.0004	ND	
BF5	0.0006	ND	0.1148	0.0176	0.0250	0.0003	ND	
FC5	0.0003	ND	0.1516	0.0092	0.0257	0.0002	ND	
BF7	0.0006	ND	0.1466	0.0164	0.0197	0.0004	ND	
RIFS1	0.0007	ND	0.1362	0.0183	0.0303	0.0003	ND	
PHASE 4 (10/1/89 - 9/30/90)								
FC1	0.0005	0.0027	0.0994	0.0100	0.0216	0.0005	0.4403	
FC2	0.0004	0.0026	0.0903	0.0099	0.0223	0.0005	0.3791	
FC2D	0.0004	ND	0.0930	0.0097	0.0212	0.0004	0.4730	
FC3	0.0004	ND	0.0494	0.0102	0.0207	0.0005	0.4651	
FC4	0.0004	ND	0.0741	0.0102	0.0236	0.0007	0.4271	
FC5	0.0003	0.0030	0.0710	0.0108	0.0252	0.0006	0.3607	
Legend:	CD	Cadmium	ZN	Zinc				
	CR	Chromium	AS	Arsenic				
	CU	Copper	HG	Mercury				
	PB	Lead	NH3	Ammonia				

Table 4.4-5 Summary of Basin F/IRA-F/RIFS Metals Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	CD	CR	CU	PB	ZN	AS	HG	NH3
24-HOUR MAXIMUM VALUES								
PHASE 1 (3/22/88 - 12/12/88)								
BF1	0.0032	0.1520	0.3851	0.0258	0.5471	0.0025	4.7	
BF2	0.0149	0.1350	1.4980	0.0614	0.8106	0.0037	7.3	
BF2C	0.0019	0.1350	0.6349	0.0397	0.5623	0.0026	7.3	
BF3	0.0036	0.2083	0.5760	0.0292	0.5054	0.0018	7.3	
BF4	0.0037	0.2858	0.5349	0.0317	0.8651	0.0024	5.0	
BF5	0.0022	0.0087	0.1758	0.0434	0.2557	0.0136	2.1	821.9
BF6	0.0015	0.0123	0.1413	0.0260	0.1449	0.0018	4.9	366.8
BF7	0.0035	0.0038	0.1174	0.0261	0.2284	0.0013	6.3	ND
PHASE 2 - STAGE 1 (12/13/88 - 2/15/89)								
BF1	0.0037	0.0149	0.0839	0.0499	0.9703	0.0024	1.5	
BF2	0.0016	0.0083	0.1226	0.0428	0.4959	0.0031	3.0	
BF2C	0.0013	0.0082	0.0983	0.0366	0.4762	0.0025	ND	
BF3	0.0016	0.0037	0.0858	0.0430	0.9151	0.0032	2.1	
BF4	0.0016	0.0038	0.1004	0.0436	1.1316	0.0026	ND	
BF5	0.0016	0.0075	0.0975	0.0260	3.3576	0.0028	ND	ND
BF6	0.0013	0.0044	0.1065	0.0312	0.1476	0.0012	ND	ND
BF7	0.0012	0.0110	0.1116	0.0247	1.0643	0.0012	ND	ND
RIFS1	0.0067	ND	0.1490	0.1080	0.1110	0.0038	ND	ND
RIFS1D	0.0065	ND	0.1570	0.0674	0.0655	0.0039	ND	ND
RIFS2	0.0032	ND	0.1680	0.0779	0.3676	0.0034	ND	ND
PHASE 2 - STAGE 2 (2/16/89 - 5/5/89)								
BF1	0.0069	0.0037	0.0804	0.0249	0.5420	0.0024		
BF2	0.0015	0.0093	0.1112	0.0311	0.6865	0.0025	ND	
BF2C	0.0009	0.0082	0.1178	0.0239	0.3462	0.0018	ND	
BF3	0.0016	0.0032	0.0983	0.0244	0.6185	0.0024	ND	
BF4	0.0015	0.0090	0.1025	0.0257	0.1040	0.0025	ND	
BF5	0.0199	0.0029	0.0694	0.0191	0.4289	ND	ND	ND
BF6	0.0008	0.0064	0.0936	0.0292	0.0819	0.0017	ND	ND
BF7	0.0019	0.0035	0.1039	0.0182	0.5766	ND	ND	ND
RIFS1	0.0040	0.0141	0.1600	0.0553	0.0854	0.0025	ND	ND
RIFS1D	0.0042	ND	0.1360	0.0381	0.3330	0.0007	ND	ND
RIFS2	0.0021	ND	0.1310	0.0385	0.0501	0.0023	ND	ND

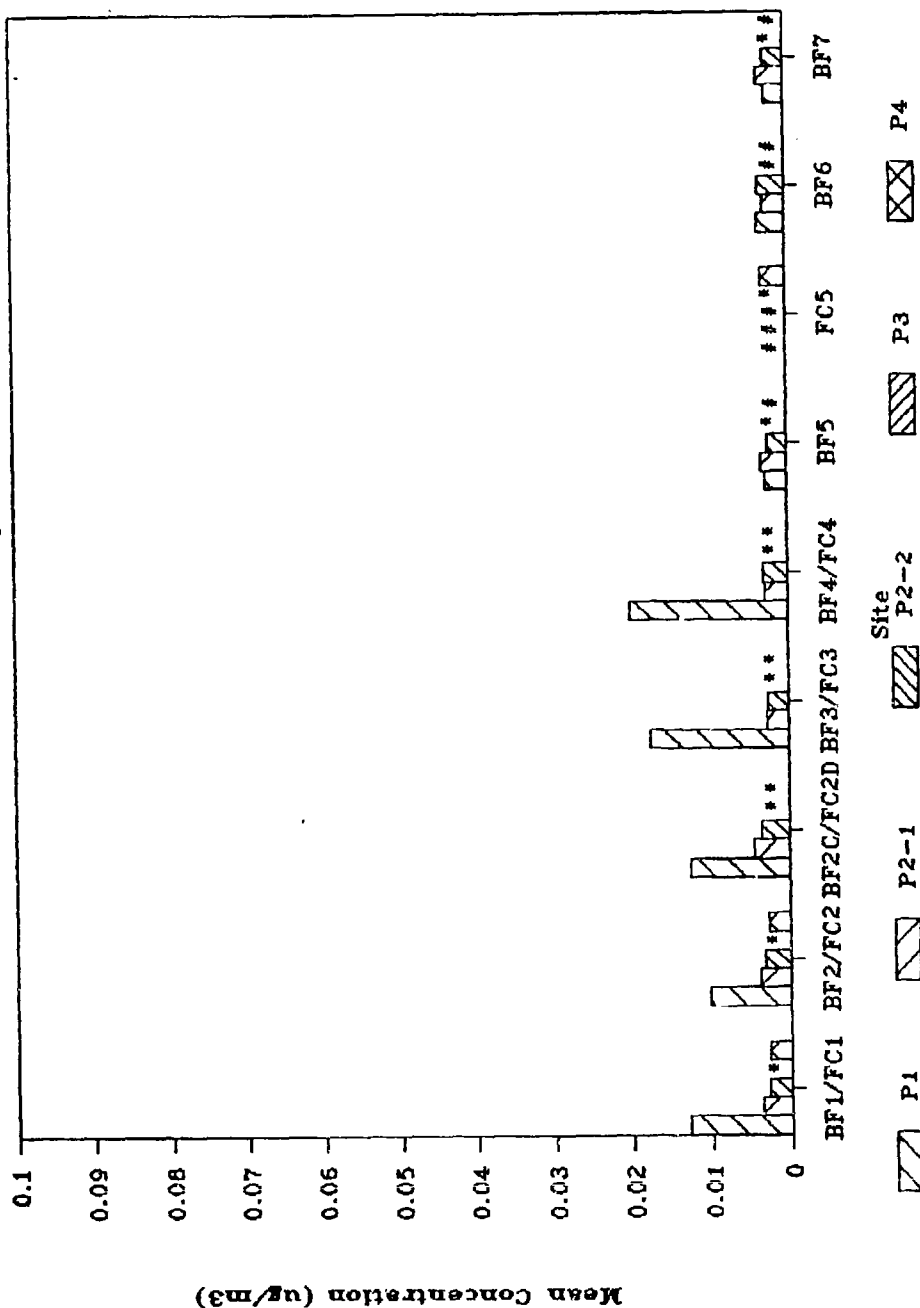
Legend:
 CD Cadmium
 CR Chromium
 CU Copper
 PB Lead
 ZN Zinc
 AS Arsenic
 HG Mercury
 NH3 Ammonia

Table 4.4-5 Summary of Basin F/IRA-F/RIFS Metals Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)(continued)

	CD	CR	CU	PB	ZN	AS	HG	NH3
24-HOUR MAXIMUM VALUES								
PHASE 3 (5/6/89 - 9/30/89)								
FC1	0.0033	ND	0.1910	0.0489	0.0272	0.0006	ND	
FC2	0.0043	ND	0.1610	0.0493	0.0268	0.0006	ND	
FC2D	0.0029	ND	0.2290	0.0502	0.0280	0.0005	ND	
BF3/FC3	0.0033	ND	0.1420	0.0475	0.0280	0.0006	ND	
BF4/FC4	0.0040	ND	0.1490	0.0482	0.0296	0.0005	ND	
BF5	0.0021	ND	0.1750	0.0471	0.0393	0.0005	ND	
FC5	0.0007	ND	0.2160	0.0141	0.0350	0.0004	ND	
BF7	0.0013	ND	0.1940	0.0411	0.0285	0.0006	ND	
RIFS1	0.0021	ND	0.2360	0.0401	0.0465	0.0007	ND	
PHASE 4 (10/1/89 - 9/30/90)								
FC1	0.0033	0.0052	0.2600	0.0360	0.0600	0.0031	2.70	
FC2	0.0038	0.0051	0.2100	0.0380	0.0600	0.0035	0.94	
FC2D	0.0040	ND	0.1900	0.0380	0.0610	0.0016	2.60	
FC3	0.0042	ND	0.0980	0.0440	0.0670	0.0040	1.10	
FC4	0.0035	ND	0.1400	0.0420	0.0730	0.0072	2.00	
FC5	0.0028	0.0150	0.1500	0.0410	0.0710	0.0030	1.00	

Legend:	CD	Cadmium	ZN	Zinc
	CR	Chromium	AS	Arsenic
	CU	Copper	HG	Mercury
	PB	Lead	NH3	Ammonia

Chromium Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

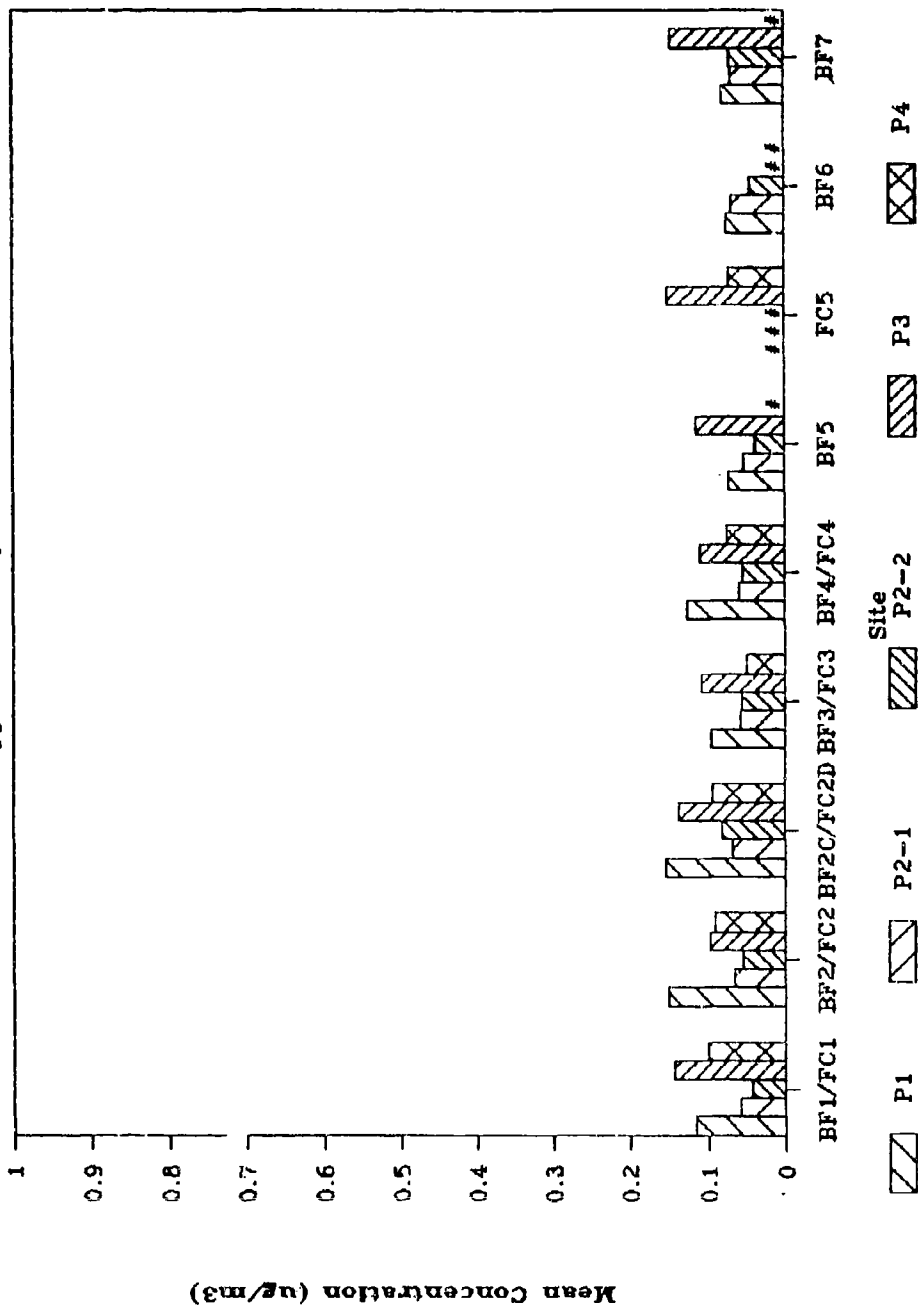
Figure 4.4-1

Chromium Results by Phase

CMP AR FY90

* MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

Copper Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

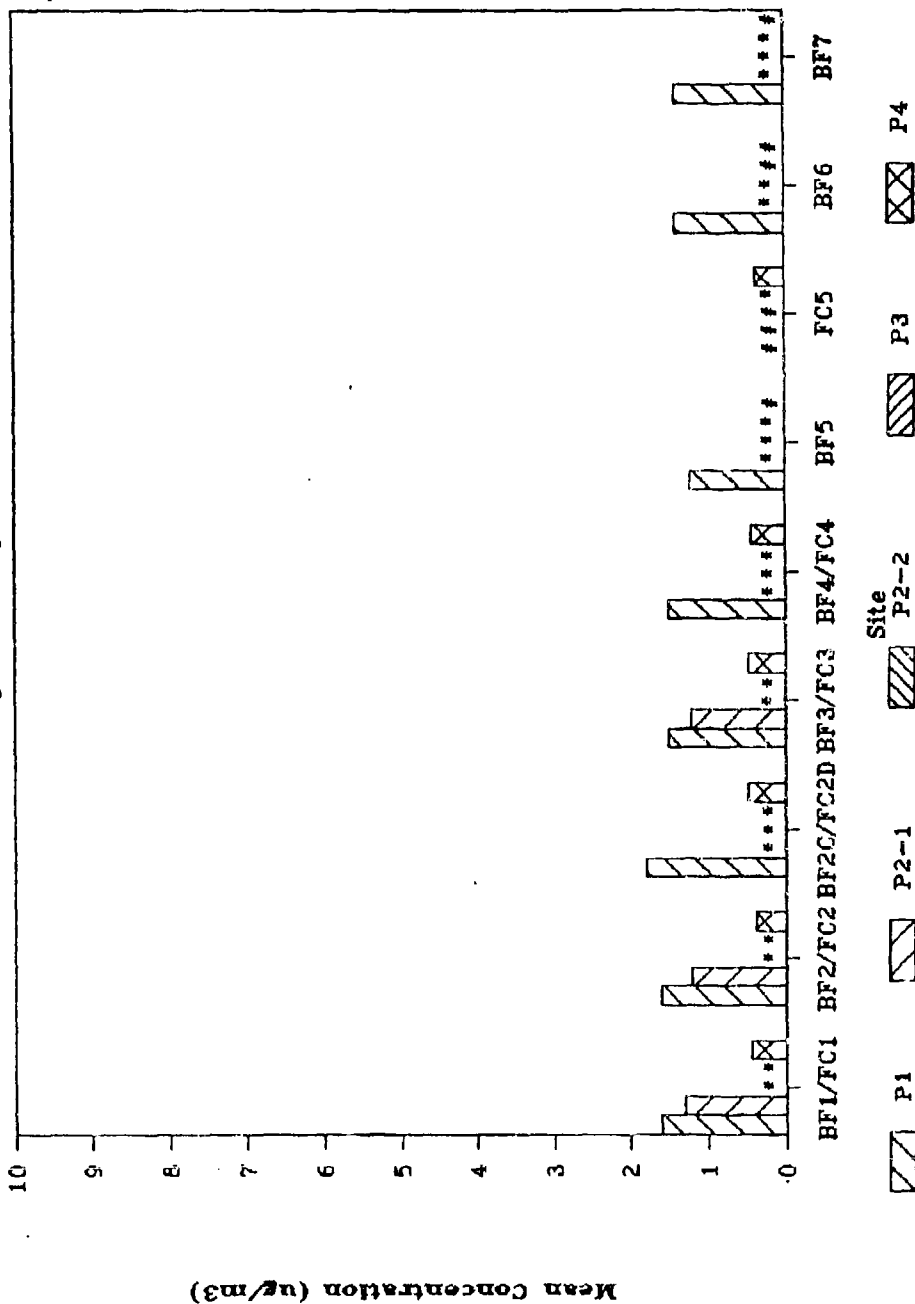
Figure 4.4-2

Copper Results by Phase

CMP AR FY90

* MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

Mercury Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

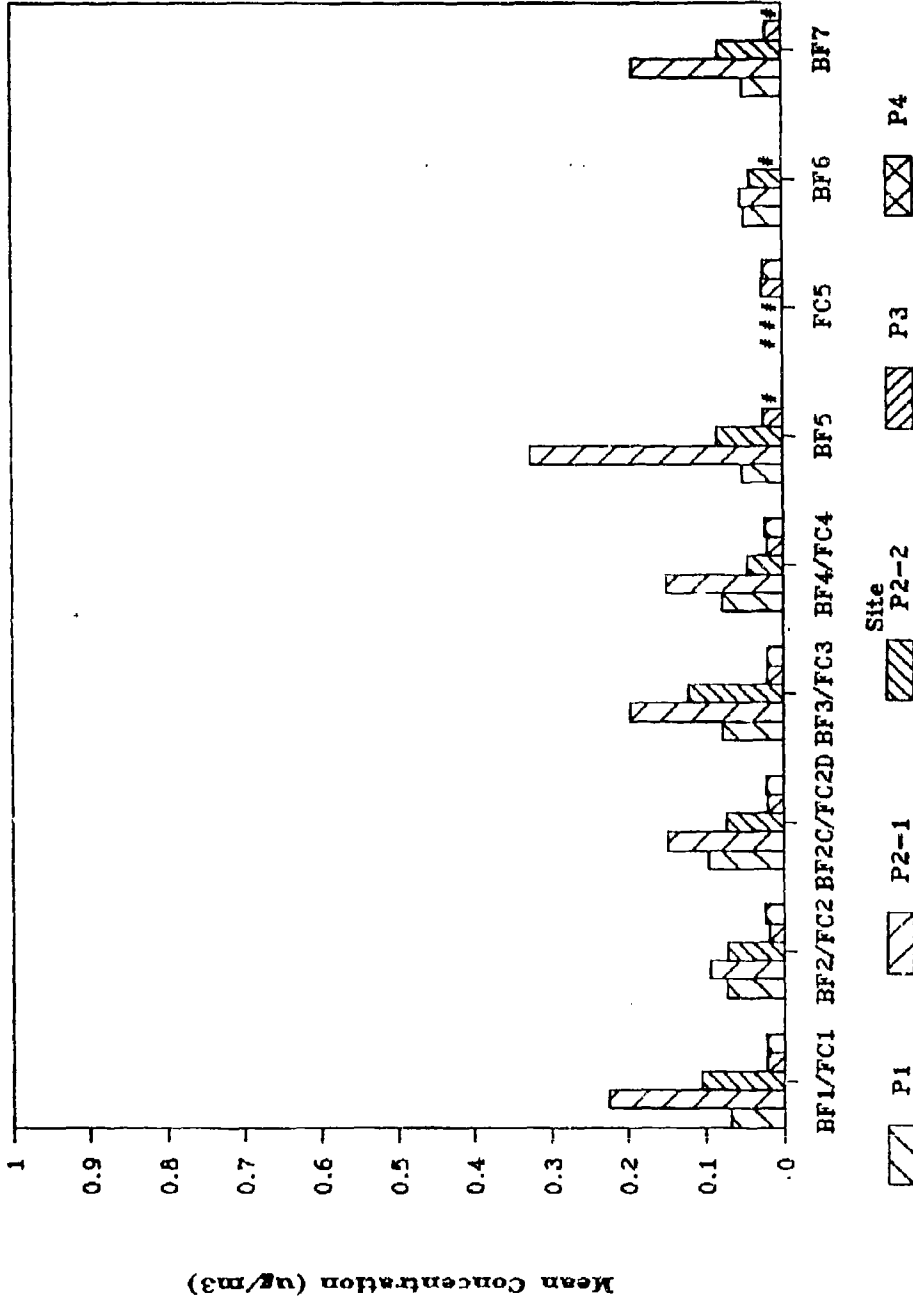
• MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

Figure 4.4-3

Mercury Results by Phase

CMP AR FY90

Zinc Results By Phase



• MAXIMUM 24-HOUR CONCENTRATION
 # NO SAMPLES TAKEN DURING THIS PHASE
 * NOT DETECTED DURING THIS PHASE

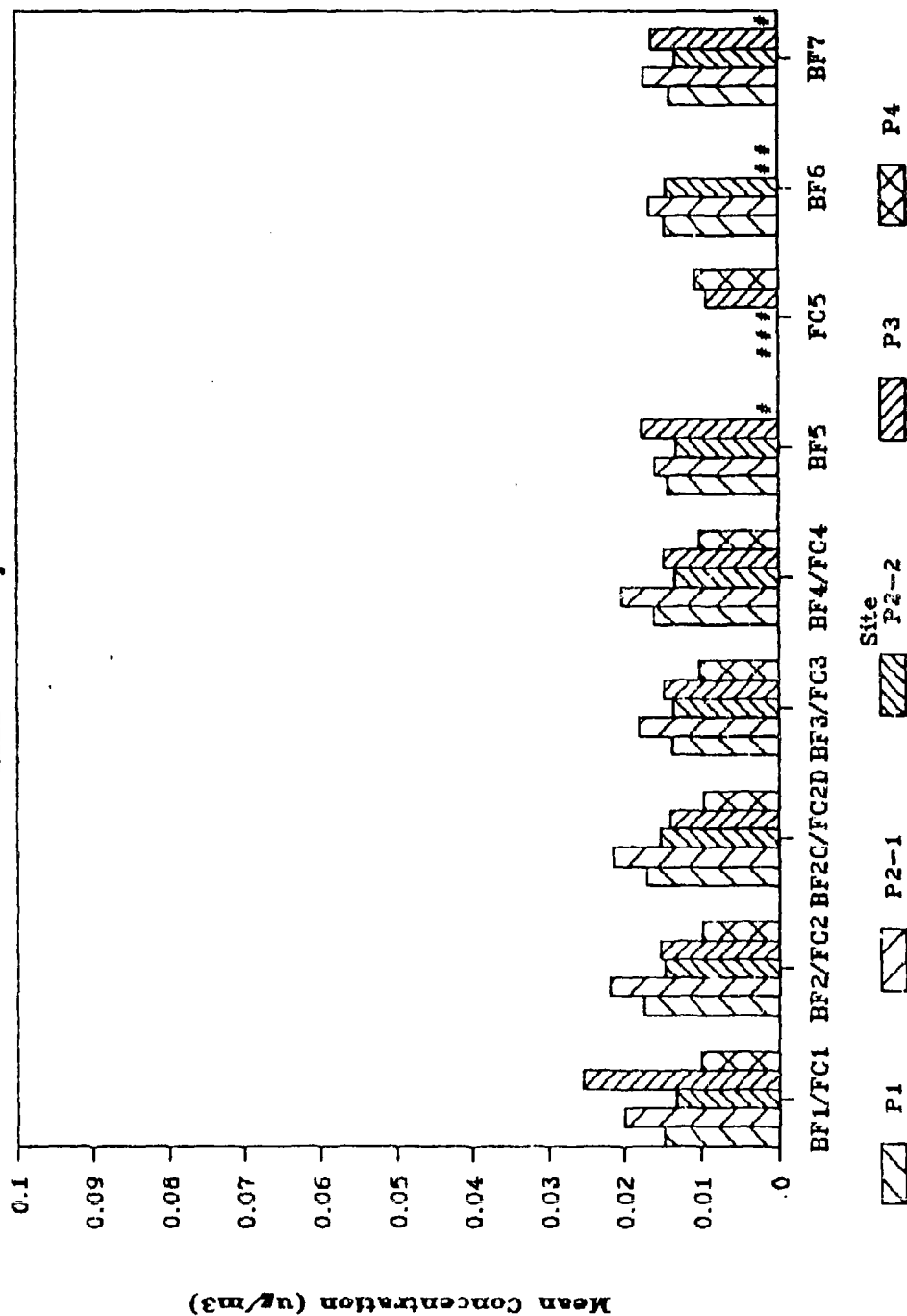
Prepared for :
 U.S. Army Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by :
 R.L. Stellar & Associates, Inc.
 Ebasco Services, Inc.

Figure 4.4-4

Zinc Results by Phase

CMP AR FY80

Lead Results By Phase



Prepared for :

U.S. Army Program Manager for

Rocky Mountain Arsenal

Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.

Ebasco Services, Inc.

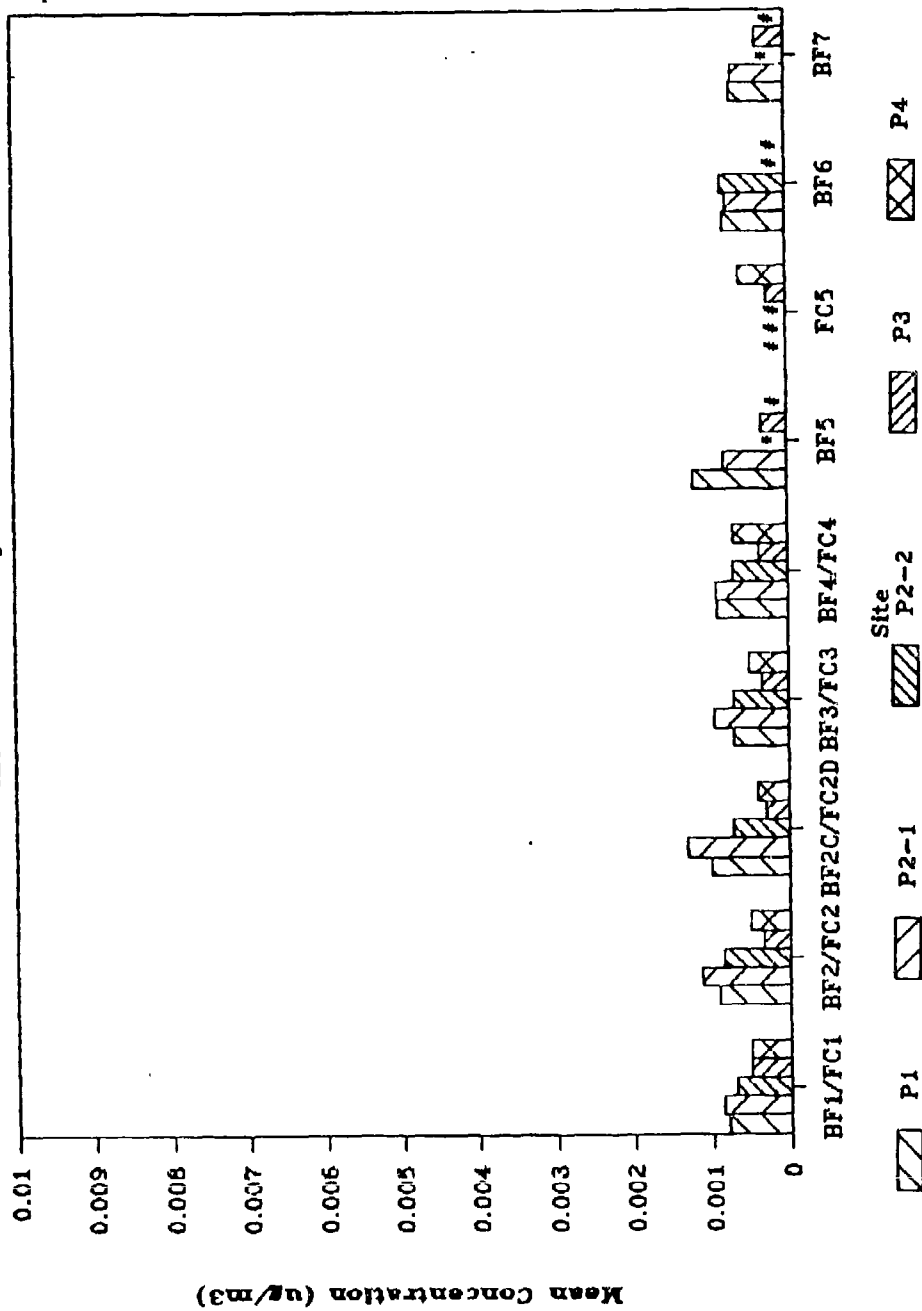
Figure 4.4-5

Lead Results by Phase

GMP AR FY80

* MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

Arsenic Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 4.4-6

Arsenic Results by Phase

CMP AR FY90

* MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

Cadmium Results By Phase

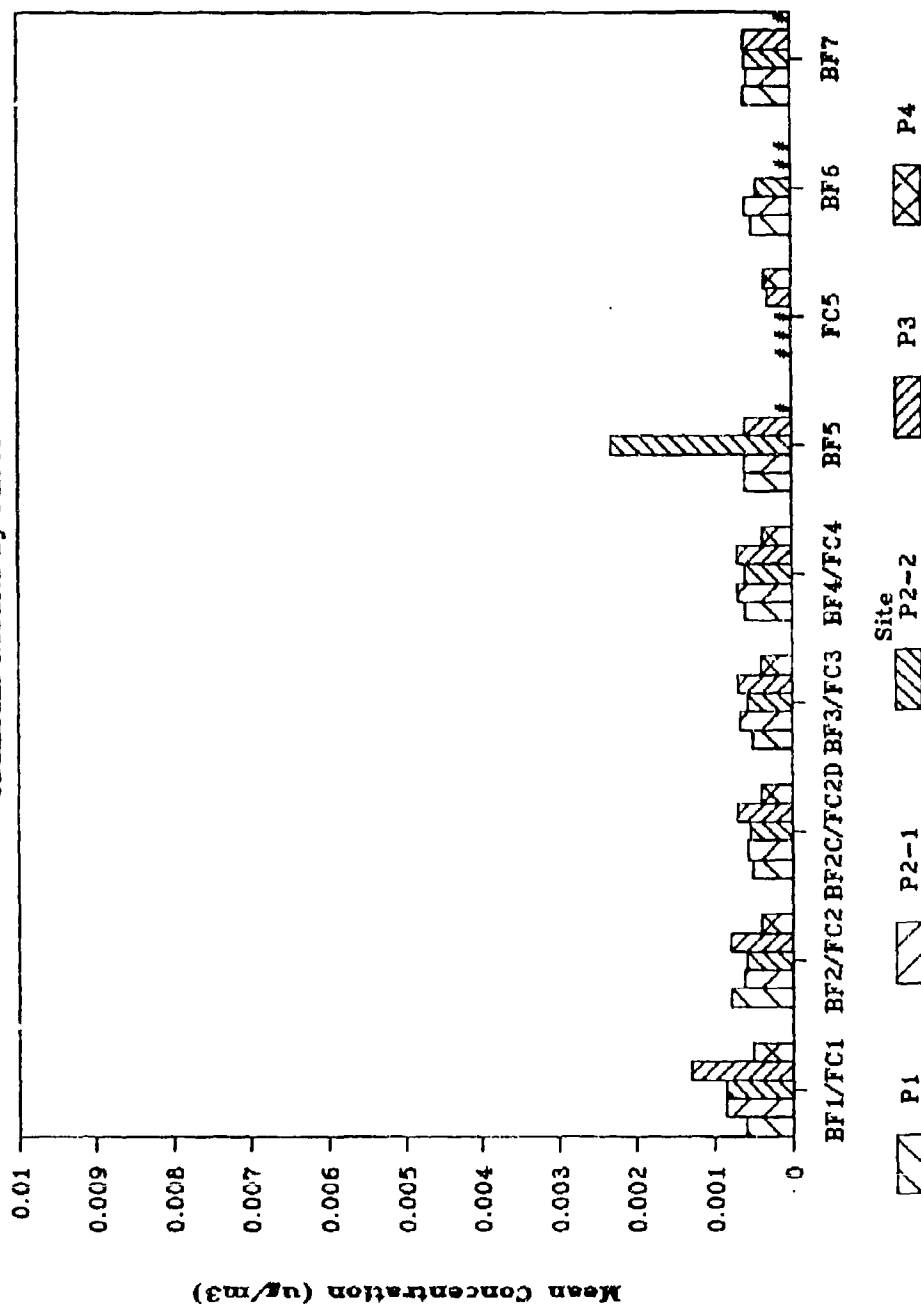


Figure 4.4-7

Cadmium Results by Phase

CMP AR FY90

Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerca City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

• MAXIMUM 24-HOUR CONCENTRATION
• NO SAMPLES TAKEN DURING THIS PHASE
• NOT DETECTED DURING THIS PHASE

mercury, appeared to be impacted by Basin F remedial operations, especially at the sites immediately around the Basin F perimeter. Chromium, for example, reached its highest levels during the Phase 1 remedial operations at the four monitoring sites immediately surrounding the Basin F perimeter (Figure 4.4-1). The maximum average value was $0.0200 \mu\text{g}/\text{m}^3$ at BF4 and the maximum 24-hour value was $0.2858 \mu\text{g}/\text{m}^3$, also at BF4; these values decreased substantially at the more distant Basin F monitoring sites (BF5, BF6 and BF7), and were comparable to maximum values at CMP monitoring sites.

During the Phase 2 period, chromium levels immediately surrounding Basin F decreased by factors of 3 to 7 and were comparable to levels at the more distant Basin F and CMP monitoring sites. Chromium was not detected at any of the sites during Phase 3, and was detected at minimal levels at FC1, FC2, and FC5 during Phase 4.

It would appear from these results that some chromium impacts occurred in the immediate vicinity of Basin F during the early stages of the remediation program. These impacts were highly localized and decreased to typical background levels at the conclusion of the remediation activities. The health impacts of the higher chromium levels during remediation, and other metals, will be discussed in Section 4.4.5.

A similar, though less conclusive, pattern was shown for copper levels in the vicinity of Basin F (Figure 4.4-2). Moderately higher copper concentrations were measured at the Basin F perimeter sites during Phase 1 and decreased with distance. The maximum average value was $0.1539 \mu\text{g}/\text{m}^3$ at BF2C and the maximum 24-hour value was $1.4980 \mu\text{g}/\text{m}^3$ at BF2. During Phase 2 maximum copper levels at the Basin F perimeter decreased to values comparable to the more distant Basin F monitoring sites and the CMP monitoring sites. However, during the Phase 3 monitoring period mean copper concentrations again increased to the highest levels measured during the 31-month monitoring period. One explanation is that this was a seasonal phenomenon, as almost all CMP monitoring sites across the Arsenal also showed increased copper levels during the Phase 3 period. Copper levels continued to decrease during Phase 4. Nevertheless, several high maximum 24-hour copper concentrations measured near the perimeter of Basin F during the Phase 1 remediation period indicate that Basin F may have been a source of copper emissions during more intensive cleanup activities.

Mercury measurements during the Phase 1 monitoring period were roughly equivalent at all seven sites (Figure 4.4-3). A maximum 24-hour value of $7.3 \mu\text{g}/\text{m}^3$ occurred during Phase 1 at BF2 and BF3. Some very sporadic, localized mercury impacts were noted during Phase 2 (Stage 1), with

minimal to no impact recorded during Phase 2 (Stage 2), and Phase 3. However, mercury was again detected at all Basin F sites at low levels during Phase 4.

Zinc concentrations followed an atypical pattern with the highest levels recorded at Basin F during the Phase 2 (Stage 1) dirt moving and landscaping period, rather than the Phase 1 remediation period (Figure 4.4-4). This could have been a function of the soil that was moved during the covering period; however, this could also have been a function of an analytic problem in that subsequent quality assurance review identified high zinc (and arsenic) levels in some TSP filters prior to sampling. The maximum average zinc level recorded in Phase 2 was $0.3260 \mu\text{g}/\text{m}^3$ at BF5; the maximum 24-hour level was $3.3576 \mu\text{g}/\text{m}^3$ at BF5. During Phase 3 and Phase 4, zinc levels at Basin F were comparable to other CMP concentrations across the Arsenal.

Arsenic and lead concentrations reflected minimal changes during Phases 1 through 4 and were comparable to other measurements at the CMP monitoring sites (Figures 4.4-5 and 4.4-6). A one time 24-hour maximum arsenic level of $0.0136 \mu\text{g}/\text{m}^3$ was measured at BF5 during Phase 1; all other 24-hour maximum values were equivalent to CMP levels. The maximum 24-hour Basin F lead value during Phase 1, $0.0614 \mu\text{g}/\text{m}^3$ at BF2, was less than the maximum CMP 24-hour value of $0.0984 \mu\text{g}/\text{m}^3$ measured at AQ5 during Phase 2, Stage 1 and less than the value $0.108 \mu\text{g}/\text{m}^3$ measured at RIFS1 (at the northeast boundary of the Arsenal) during Phase 2, Stage 1. There appeared to be no Basin F impacts from these metals.

Cadmium concentrations indicated small differences at all Basin F stations during the Phase 1 and Phase 2 periods (Figure 4.4-7). During Phase 3, cadmium concentrations were actually slightly higher than during the earlier Basin F remediation periods, but overall cadmium levels were very low; the highest average concentration was $0.0027 \mu\text{g}/\text{m}^3$ measured at BF2. There is no explanation why cadmium levels were slightly higher in the vicinity of Basin F during the Phase 3, post-remedial phase. Cadmium values were again lower during the phase 4 (FY90) period. The highest 24-hour cadmium concentration, $0.0253 \mu\text{g}/\text{m}^3$, was measured at CMP Station AQ5 at the extreme southern end of the Arsenal. As will be discussed in Section 4.4.5, all cadmium concentrations were well below general toxic guidelines.

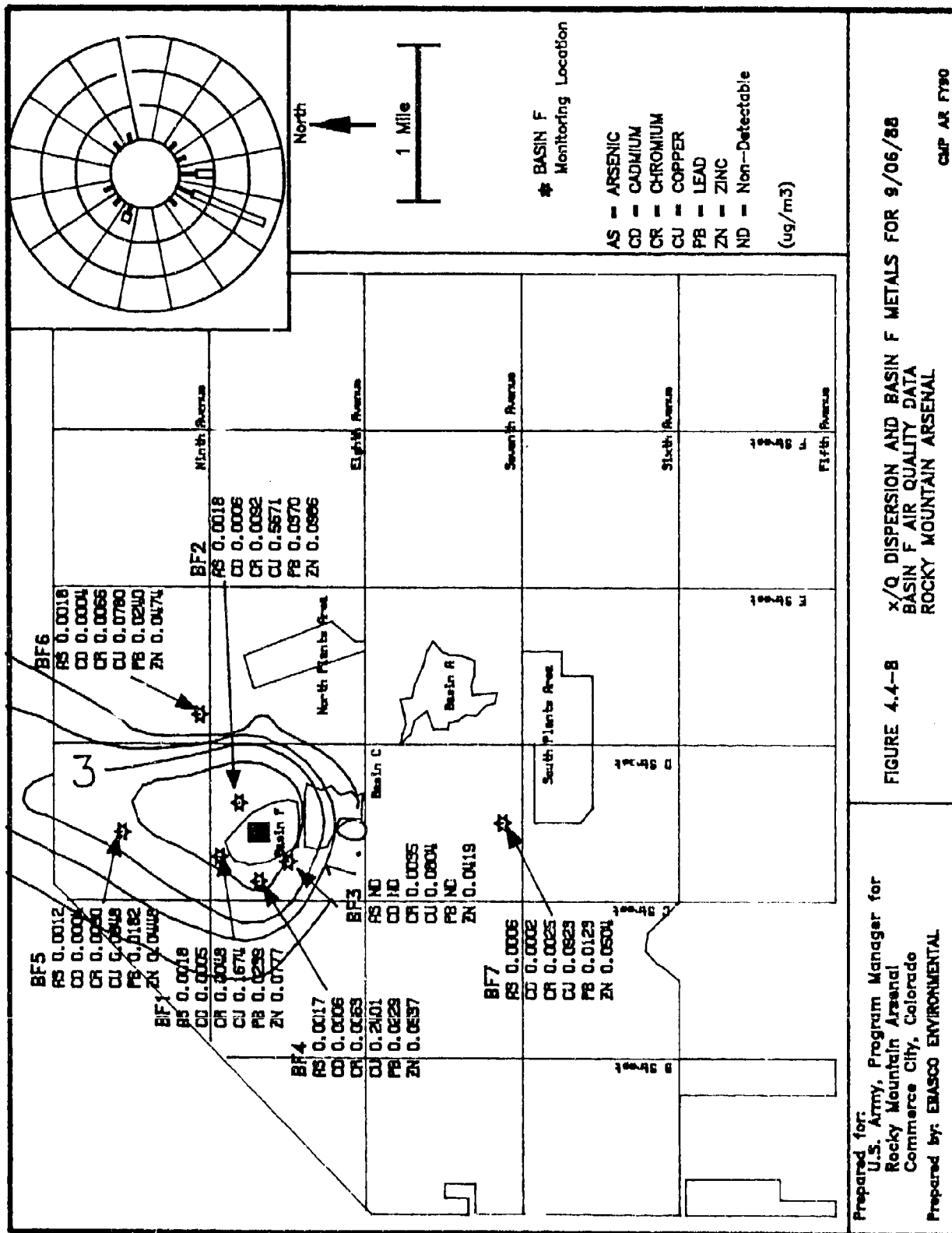
Ammonia was monitored during the Basin F program at three sites (BF5, BF6 and BF7) on 1 day per week which was predicted to have the greatest impacts from Basin F activities. Monitoring was conducted during both Phase 1 and Phase 2. Detectable levels were collected only during Phase 1 with

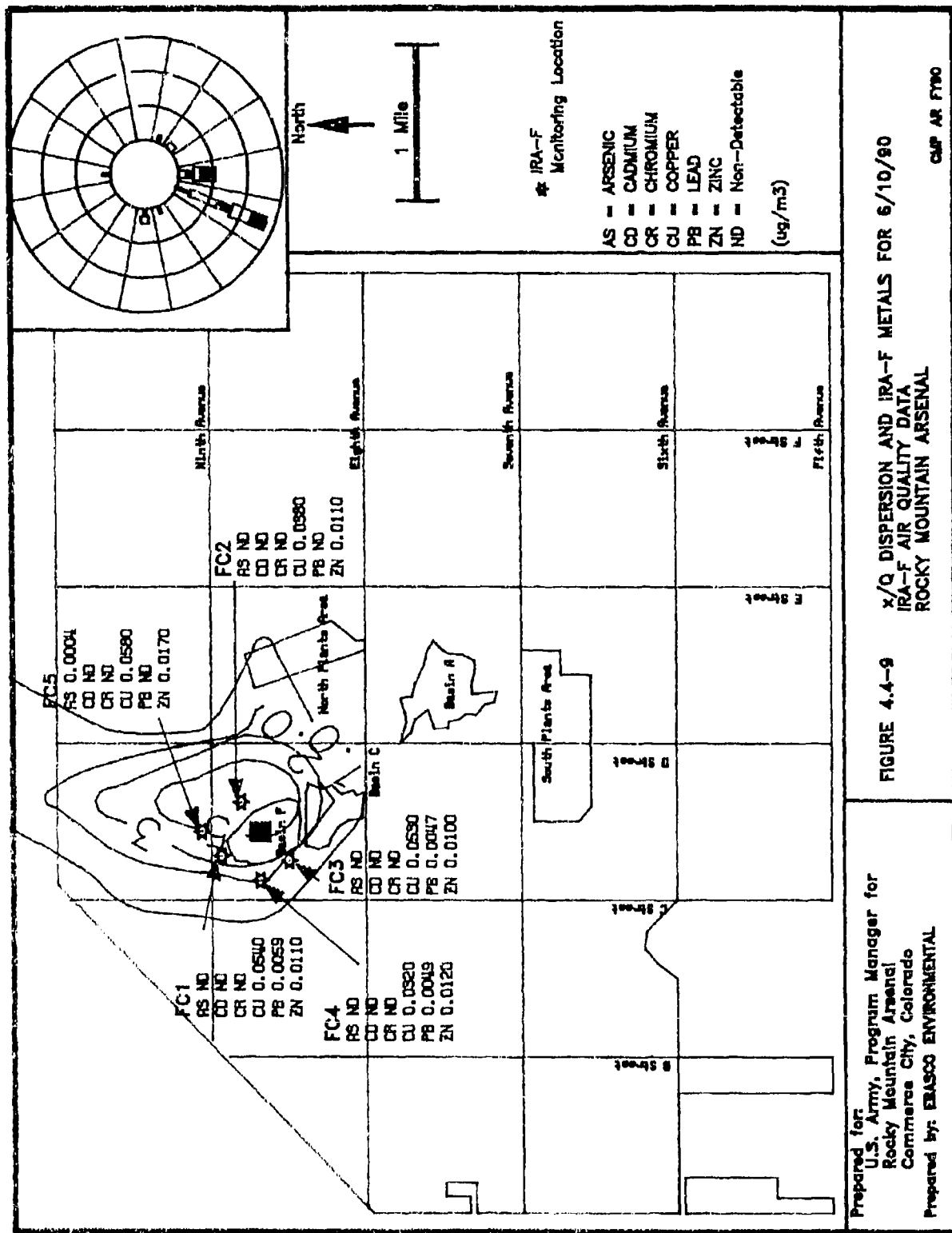
a maximum reading of $822 \mu\text{g}/\text{m}^3$ at BF5 and a highest average reading of $284 \mu\text{g}/\text{m}^3$, also at BF5. No ammonia sampling was conducted in Phase 3 or Phase 4.

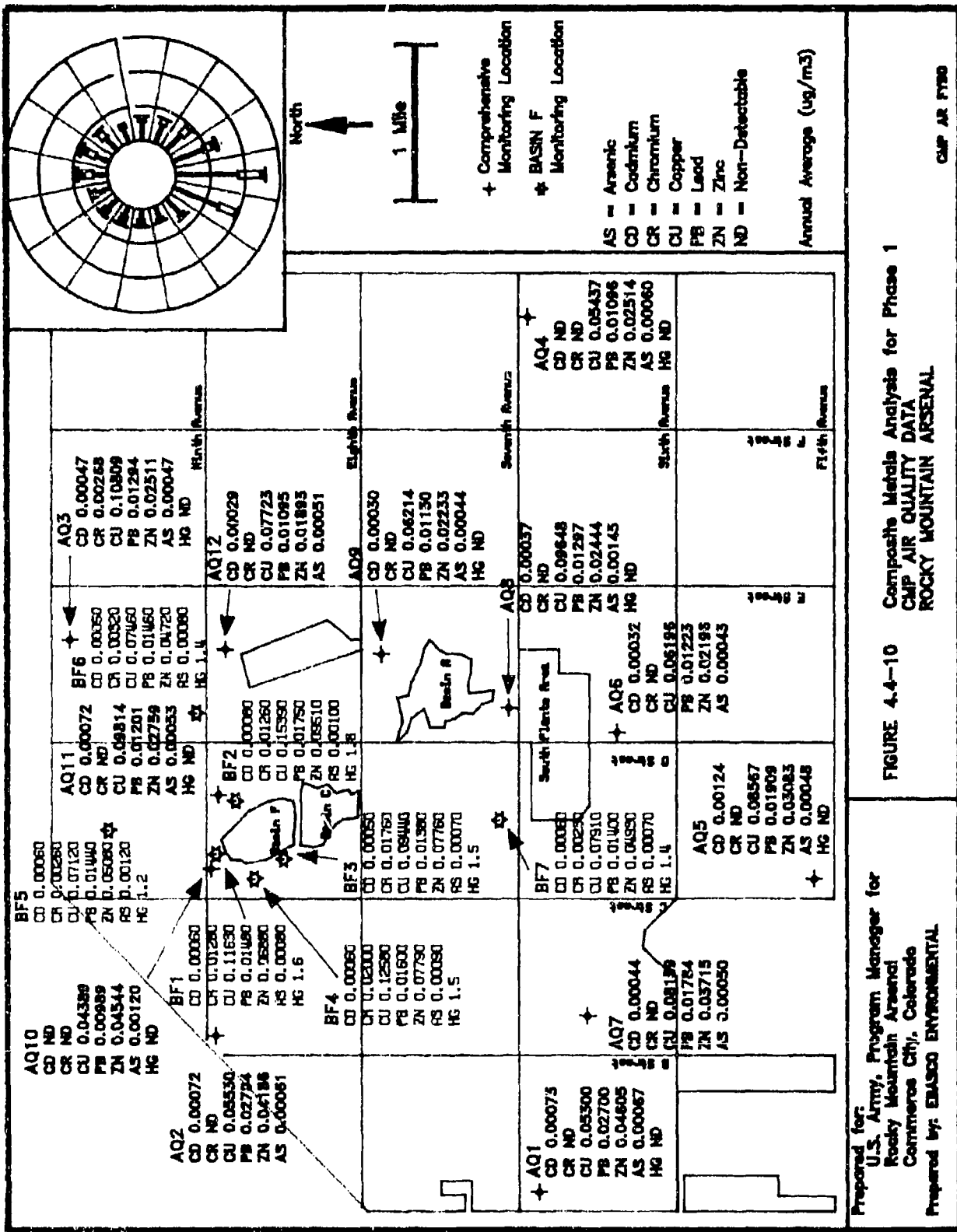
Another approach to assessing remedial progress is to consider Basin F impacts that were observed on individual days during the remedial and post-remedial periods. All Basin F air monitoring during the Phase 1 period was conducted for worst-case, 24-hour periods based on dispersion model analysis and remedial activity. An example of the dispersion of metals resulting from Basin F remedial activities (Phase 1) is shown in Figure 4.4-8. This figure shows metals concentrations for September 6, 1988, with X/Q dispersion values overlaying the monitoring data for seven Basin F stations. This type of analysis identifies, to the fullest extent, the potential dispersion of metals and other contaminants resulting from remedial actions. On this day winds were from the south-southwest at moderate speeds. Peak levels for most metals occurred at the closest downwind sites. Sites further downwind, as well as upwind, from Basin F measured lesser values, thereby substantiating the dispersion pattern and identifying Basin F as a potential metals source. Consider next the dispersion of metals on June 10, 1990, a day in the FY90 post-remedial period (Phase 4). The X/Q dispersion pattern and the reported concentrations for this day are shown in Figure 4.4-9. The dispersion pattern and meteorological conditions are similar to the Phase 1 day. However, a decrease in concentrations is evident for several metals. These data further support the conclusion that Basin F impacts occurred during Phase 1, but were significantly reduced by Phase 4.

4.4.3.3 Combined CMP and Basin F Data Analyses

Individual CMP and Basin F metals monitoring data for the remedial and post-remedial phases of the monitoring programs have been shown in Tables 4.4-3 and 4.4-5. Figures 4.4-10 and 4.4-10A provide a depiction of all available average and 24-hour maximum metals data across the Arsenal complex during the Phase 1 remediation phase. Figures 4.4-11 and 4.4-11A provide the same information for the most recent Phase 4 post-remedial period. All maximum periods are 24 hours except for monitoring on May 11, 1990, when sampling was conducted for approximately 6 hours. Corresponding wind roses are also shown in these figures. These data confirm individual results previously discussed in addition to showing the influences of meteorology and atmospheric dispersion impacts, distance from a potential source, and the source influence itself. For example, Figures 4.4-10 and 4.4-10A show average and maximum concentrations during Phase 1 for CMP sites and seven Basin F sites, and indicate the highest levels of chromium, copper, lead and zinc adjacent to Basin F and immediately downwind from the source, as reflected by the prevailing wind flow. Station BF2, which was located in the northeast corner of the Basin immediately downwind from the prevailing



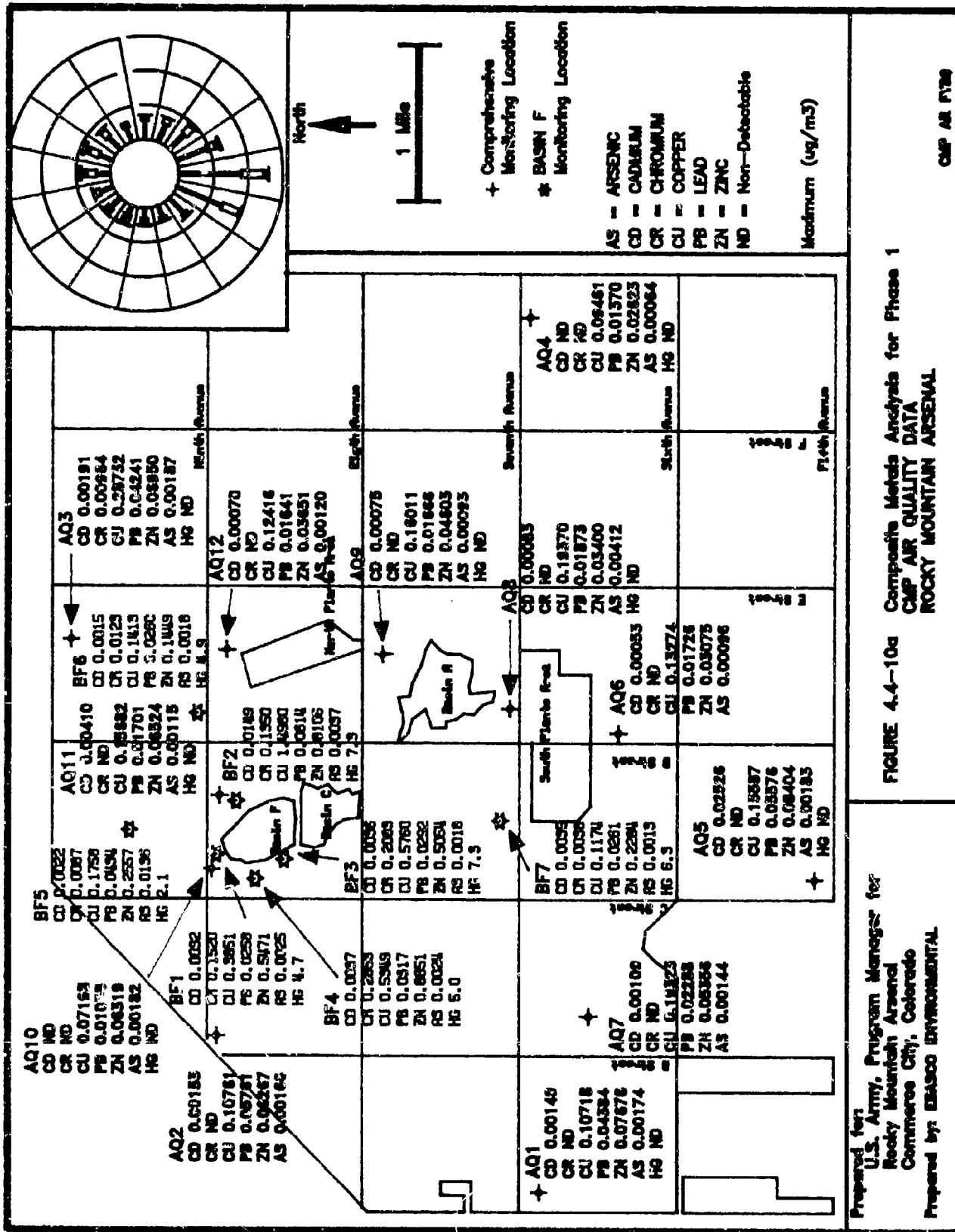




Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: EMASCO ENVIRONMENTAL

FIGURE 4.4-10 Composite Metals Analysis for Phase 1
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

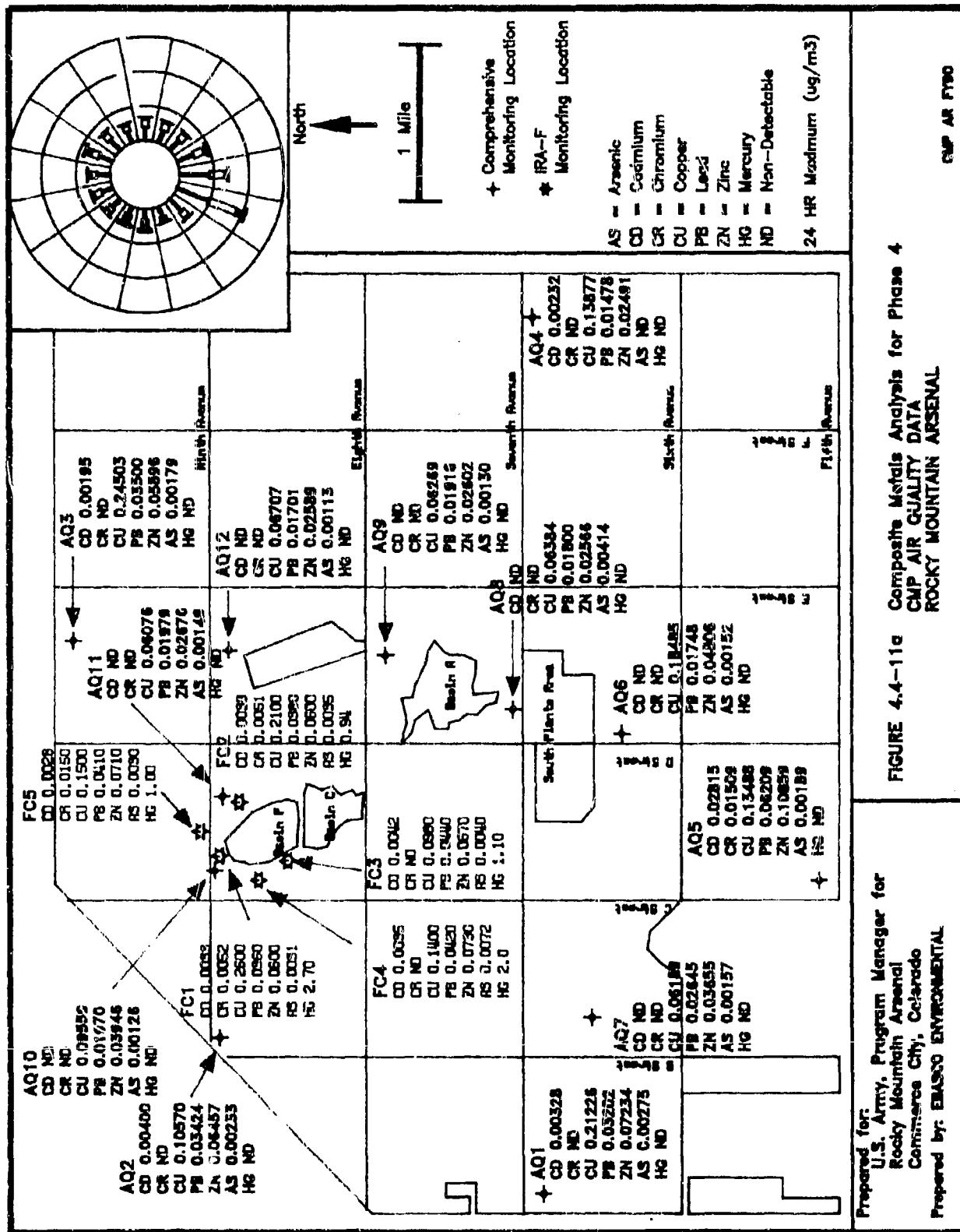
CMP AIR PM10



Prepared for:
U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by: EASCO ENVIRONMENTAL

FIGURE 4.4-10a Composite Metals Analysis for Phase 1
CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

CMP AIR P128



flow and which was the closest station to much of the remedial activity, measured highest concentrations for most metals (there were several exceptions, i.e., the highest chromium levels were at BF4). In general, except for cadmium and lead, metals values decreased with distance from the Basin F source. It is noted that several metals compounds (i.e., cadmium, lead, and arsenic) showed highest concentrations along the RMA boundaries during the Phase 1 period, suggesting that there were neither Basin F nor Arsenal sources.

Figures 4.4-11 and 4.4-11A show the distribution of average and maximum metals concentrations at Basin F and across RMA during the Phase 4 post-remedial period. All metals levels were typical of background regional levels. Dispersion conditions were similar to the previous remedial phase periods, inferring that any metals components that were indigenous to the Basin F compound were evident only during the remediation process, although as previously noted, cadmium was slightly higher in the vicinity of Basin F during the Phase 3 period.

4.4.4 ANALYSIS OF METALS SOURCE FACTORS

It appears that metals monitored in the RMA vicinity resulted from many causes. Several metal elements may have been deposited in the soil around Basin F; others may have resulted from industrial and transportation activities in the Denver metropolitan area. There were overriding baseline levels of all the metals components typical of the area's semi-urban environment. With the exception of transportation and industry related components, the metals were probably transported primarily by wind-blown dust and soil particles. This was evident in a CMP study conducted in FY89 (Stollar, 1990) which showed the relationship between total metals (the sum of concentrations of all targets) collected under the Basin F program and TSP levels at Basin F during all remediation phases for Site BF2. Although there were typical variations in this database (the correlation factor was 0.68), the general inference was that the higher the TSP levels, the higher the levels of metals collected in the sample filters.

An analysis of average and maximum metals concentrations for FY90 indicated that, as in past years, high metals concentrations at RMA monitoring sites resulted from a number of sources and occurred under several favorable meteorological conditions. In the CMP FY88 Data Assessment Report, Table 4.2-16 showed in almost every case that the highest metal concentrations for each element at each monitoring site were associated with average 24-hour winds in excess of 10 mph and wind gusts in excess of 25 mph (Stollar, 1990). In contrast, the majority of high metals episodes during FY89 resulted from "brown cloud" inversion impacts from metropolitan Denver, as shown in Table 4.4-6

Table 4.4-6 Observed Maximum Metals Concentrations and Associated Wind Speeds at CMP Sites

Metal	Maximum Concentration ($\mu\text{g}/\text{m}^3$)	Phase	Date	Maximum Wind Speed Gust (mph)	Average Wind Speed (mph)	# Hours Gust >22 mph	Dominant Wind Direction
STATION AQ1							
Cadmium	0.00426	P2-S2	03-11-89	14.9	7.8	0	SSW
Chromium	ND	--	--	-	-	-	-
Copper	0.21695	P2-S2	03-11-89	14.9	7.8	0	SSW
Lead	0.06026	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.09431	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00487	P2-S2	03-17-89	49.5	14.9	8	WNW
Mercury	ND	-	-	-	-	-	-
STATION AQ2							
Cadmium	0.00400	P4	06-28-90	23.7	11.4	0	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.17522	P3	05-28-89	25.8	10.8	3	SSW
Lead	0.05761	P1	03-22-88	25.4	9.2	5	NNE
Zinc	0.06964	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00582	P2-S2	03-17-89	49.5	14.9	8	WNW
Mercury	ND	-	-	-	-	-	-
STATION AQ3							
Cadmium	0.00573	P2-S1	01-28-89	39.7	14.6	13	N
Chromium	0.00964	P1	07-14-88	18.2	9.8	0	SSW
Copper	0.28732	P1	09-24-88	14.1	8.6	0	S
Lead	0.05884	P2-S1	02-09-89	17.6	5.9	0	S
Zinc	0.07002	P2-S1	01-04-89	16.9	6.3	0	S
Arsenic	0.00424	P2-S1	02-15-89	20.3	6.0	0	NNW
Mercury	ND	-	-	-	-	-	-
STATION AQ4							
Cadmium	0.00232	P4	01-07-90	26.9	9.0	0	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.13876	P4	06-28-90	23.7	11.4	0	SSW
Lead	0.03476	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.04977	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00262	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-

Table 4.4-6 Observed Maximum Metals Concentrations and Associated Wind Speeds at CMP Sites (continued)

Metal	Maximum Concentration ($\mu\text{g}/\text{m}^3$)	Phase	Date	Maximum Wind Speed Gust (mph)	Average Wind Speed (mph)	# Hours Gust >22 mph	Dominant Wind Direction
STATION AQ5							
Cadmium	0.02815	P4	12-12-89	24.1	10.7	0	W
Chromium	0.01508	P4	05-07-90	39.9	10.4	1	SSW
Copper	0.19235	P2-S1	01-04-89	16.9	6.3	0	S
Lead	0.09844	P2-S1	02-09-89	17.6	5.9	0	S
Zinc	0.11596	P2-S1	01-04-89	16.9	6.3	0	S
Arsenic	0.00455	P2-S1	02-15-89	20.3	6.0	0	NNW
Mercury	ND	-	-	-	-	-	-
STATION AQ6							
Cadmium	0.00165	P2-S2	04-22-89	28.8	12.2	6	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.18485	P4	06-28-90	23.7	11.4	0	SSW
Lead	0.02710	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.04859	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00243	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-
STATION AQ7							
Cadmium	0.00197	P2-S2	04-22-89	28.8	12.2	6	SSW
Chromium	0.01021	P2-S2	03-11-89	14.9	7.8	0	SSW
Copper	0.19323	P1	04-03-89	26.8	11.9	4	WSW
Lead	0.05727	P3	06-21-89	31.7	10.5	7	SW
Zinc	0.29081	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00237	P2-S2	03-11-89	14.9	7.8	0	SSW
STATION AQ8							
Cadmium	0.00184	P2-S2	04-04-89	41.9	11.3	7	NW
Chromium	ND	-	-	-	-	-	-
Copper	0.19370	P1	04-03-88	26.8	11.9	4	WSW
Lead	0.02938	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.05974	P2-S2	04-22-89	28.8	12.2	6	SSW
Arsenic	0.00737	P2-S2	05-04-89	50.8	9.0	6	ENE
Mercury	ND	-	-	-	-	-	-

Table 4.4-6 Observed Maximum Metals Concentrations and Associated Wind Speeds at CMP Sites (continued)

Metal	Maximum Concentration ($\mu\text{g}/\text{m}^3$)	Phase	Date	Maximum Wind Speed Gust (mph)	Average Wind Speed (mph)	# Hours Gust >22 mph	Dominant Wind Direction
STATION AQ9							
Cadmium	0.00124	P2-S2	03-11-89	14.9	7.8	0	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.16011	P1	11-04-88	36.4	23.9	7	WNW
Lead	0.03194	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.05455	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00271	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-
STATION AQ10							
Cadmium	0.00188	P2-S2	03-11-89	14.9	7.8	0	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.17385	P2-S2	03-11-89	14.9	7.8	0	SSW
Lead	0.03528	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.06887	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00261	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-
STATION AQ11							
Cadmium	0.00410	P1	05-03-88	33.0	6.5	1	ENE
Chromium	ND	-	-	-	-	-	-
Copper	0.17148	P3	07-03-89	47.8	12.0	8	SSW
Lead	0.02921	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.07075	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00270	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-
STATION AQ12							
Cadmium	0.00070	P1	04-21-88	25.7	10.8	5	NE
Chromium	0.01286	P2-S2	03-11-89	14.9	7.8	0	SSW
Copper	0.18421	P3	05-28-89	25.8	10.8	3	SSW
Lead	0.03038	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.07885	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00428	P2-S2	03-11-89	14.9	7.8	0	SSW

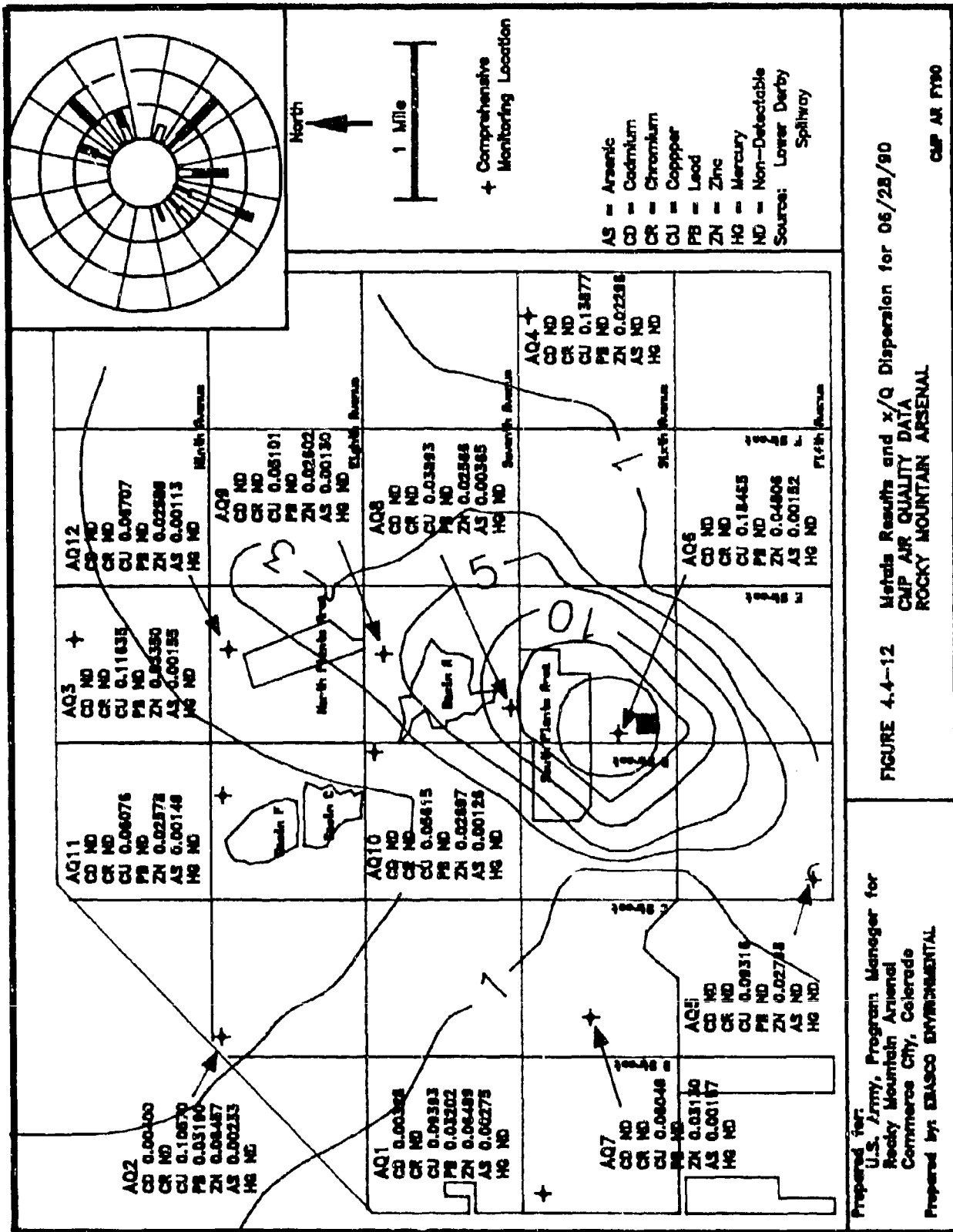
Note: FY89 includes data from samples that missed the laboratory holding time for analysis.

of the FY89 Data Assessment Report (Stollar, 1990). In fact, two-thirds of the cases with the highest metals levels occurred during three winter "brown cloud" episodes (January 4, February 9, and March 11, 1989). Very high TSP and PM-10 levels at all RMA monitoring sites were also recorded on these dates, even though wind speeds were not very strong or gusty. Prevailing winds in all cases were from the south or southwest, indicating that impacts were from metropolitan Denver.

Table 4.4-6 is an update of maximum 24-hour metals concentrations including the FY90 metals data and encompassing the entire 3 years of CMP monitoring. The majority of high concentrations for all elements still occurred during FY88 and FY89; however, there were two elements with maximum concentrations measured in FY90. The highest cadmium level for the 3-year period was $0.028 \mu\text{g}/\text{m}^3$ measured at AQ5 at the southern RMA boundary on December 12, 1989. Wind speeds on this day averaged 10.7 mph with gusts up to 24 mph, mainly from the west. The highest chromium concentration, $0.015 \mu\text{g}/\text{m}^3$, was also measured at AQ5 on May 7, 1990. Wind speeds averaged 10.4 mph and were from the south-southwest with peak gusts of nearly 40 mph.

These data indicate that strong, gusty winds remained a principal criteria for high metals levels at RMA during FY90. Also, even though inversion conditions were less severe during the winter of FY90, above average metals concentrations occurred on days when a brown cloud was observed over Denver and winds were blowing in the direction of the Arsenal. On a number of days including October 25 and December 5, 1989, and January 5, January 17, February 16, June 28, and September 14, 1990, above average metals concentrations were experienced at the Arsenal with brown cloud conditions over Denver. These days were identified in the CMP visibility study discussed in Section 6.0.

Higher metals levels, in many cases, were due to a combination of factors. For example, on June 28, 1990, wind speeds were moderate at 11.4 mph with peak gusts of 24 mph. Figure 4.4-12 shows the dispersion pattern for a 24-hour period with a potential source at the Lower Derby Lake spillway. A brown cloud was observed over Denver during the morning hours. At AQ2 near the RMA perimeter, the highest cadmium concentration recorded at the site was $0.004 \mu\text{g}/\text{m}^3$. Because of its proximity to metropolitan Denver and the prevalence of south-southwesterly winds, the high cadmium concentration at AQ2 most likely resulted from both the urban influence and moderate winds. A peak copper concentration of $0.185 \mu\text{g}/\text{m}^3$ at AQ6, however, was probably associated with construction activity from the Lower Derby Lake spillway, upwind from the site. On this day, TSP levels at AQ6 reached $320 \mu\text{g}/\text{m}^3$, the highest value recorded at this station over the 3-year period.



The high copper level appears to be a by-product of the high TSP level resulting from spillway construction and strong to moderate winds.

During the Basin F remediation period, higher levels of chromium, copper, zinc and mercury were identified in the immediate vicinity of the disturbed area. During the post-remedial period, however, Basin F monitoring stations reported significantly reduced metals concentrations that were comparable to the CMP interior sites. It is likely that some metal components are currently indigenous to the Arsenal soil.

While higher metals continued to be a function of strong and gusty winds, especially downwind from local construction and remediation activities, metals concentrations were generally higher during fall and winter inversion periods than under high wind scenarios. Table 4.4-7 shows average and 24-hour maximum seasonal metals concentrations for the 3-year monitoring period. Stations AQ3 and AQ5 were monitored every 6th day since the start of the CMP. The highest cadmium, lead, zinc, and arsenic levels for both the average and 24-hour maximum values occurred in the fall or winter seasons. During spring when winds were frequently the strongest, lower concentrations were experienced for most metals except chromium, which was detected only during the spring and summer. On the other hand, copper and chromium levels were reported at their highest during summer.

Table 4.4-8 below summarizes the locations of maximum metals concentrations from both the CMP and Basin F monitoring programs throughout the 31-month period. The implications of maximum short-term (24-hour) and long-term metals concentration with respect to toxic guidelines will be discussed in the next section.

Table 4.4-7 Seasonal Metals and Arsenic Concentrations by Site (in $\mu\text{g}/\text{m}^3$)

Season	Site	Cadmium	Chromium	Copper	Lead	Zinc	Arsenic
AVERAGE							
Fall	AQ3	0.00047	*	0.07664	0.01380	0.02557	0.00050
	AQ5	0.00154	*	0.07819	0.02353	0.03689	0.00060
	AQ5B	0.00155	*	0.13499	0.02373	0.03917	0.00065
Winter	AQ3	0.00066	*	0.08470	0.01197	0.02296	0.00066
	AQ5	0.00069	*	0.07314	0.02120	0.03448	0.00067
	AQ5B	0.00069	*	0.09932	0.02139	0.03854	0.00089
Spring	AQ3	0.00063	*	0.08002	0.01111	0.01820	0.00044
	AQ5	0.00126	0.00377	0.07647	0.01429	0.02278	0.00046
	AQ5B	0.00119	0.00388	0.10319	0.01360	0.02273	0.00045
Summer	AQ3	0.00075	0.00433	0.13047	0.01228	0.02507	0.00054
	AQ5	0.00092	*	0.08446	0.01466	0.02743	0.00047
	AQ5B	0.00099	*	0.14583	0.01408	0.02913	0.00040
24-HOUR MAXIMUM							
Fall	AQ3	0.00191	*	0.18462	0.04241	0.06950	0.00133
	AQ5	0.02815	*	0.13472	0.06209	0.10859	0.00189
	AQ5B	0.02671	*	0.25871	0.05838	0.10198	0.00383
Winter	AQ3	0.00574	*	0.24503	0.05884	0.07002	0.00424
	AQ5	0.00528	*	0.19235	0.09844	0.11596	0.00455
	AQ5B	0.00551	*	0.24956	0.09193	0.18504	0.00428
Spring	AQ3	0.00192	*	0.21826	0.04981	0.05903	0.00148
	AQ5	0.02527	0.01509	0.15587	0.03376	0.04866	0.00108
	AQ5B	0.02352	0.02659	0.21541	0.02948	0.04570	0.00142
Summer	AQ3	0.00178	0.00767	0.28732	0.03423	0.04549	0.00187
	AQ5	0.00751	*	0.18425	0.03032	0.05122	0.00175
	AQ5B	0.00695	*	0.24453	0.03605	0.05588	0.00166

Includes data for CMP FY88, FY89, and FY90.

Table 4.4-8 Maximum Concentrations Measured at RMA for CMP and Basin F/IRA-F Concurrent Programs ($\mu\text{g}/\text{m}^3$)

Metal	Maximum Long-Term Average Concentration	Location	Phase	Maximum 24-Hour Concentration	Location	Phase
Arsenic	0.0025	AQ36	P4	0.0136	BF5	P1
Cadmium	0.0027	FC2	P3	0.0281	AQ5	P4
Chromium	0.0200	BF4	P1	0.2858	BF4	P1
Copper	0.1539	BF2	P1	1.4980	BF2	P1
Lead	0.0573	AQ7	P3	0.0984	AQ5	P2-S1
Zinc	0.3260	BF5	P2-S1	3.3576	BF5	P2-S1
Mercury	1.8000	BF2	P1	7.3000	BF2	P1

4.4.5 ASSESSMENT OF METALS CONCENTRATIONS RELATIVE TO TOXIC GUIDELINES

In order to assess the significance of the measured metals concentrations relative to health standards and available toxic guidelines, a literature search was performed to compile standards and guidelines. This was necessary because the EPA and the State of Colorado have promulgated standards and published air toxic guidelines only for lead. Sources that were reviewed included the ACGIH TLV Handbook, the NIOSH Pocket Guide to Chemical Hazards, and the NATICH Database Report on State, Local, and EPA Air Toxic Activities (ACGIH, 1986; NIOSH, 1985; U.S. Department of Commerce, 1988).

The tabulation of guideline concentrations is presented in Table 4.4-9. For each target metal, the name and Chemical Abstract number is presented, along with Threshold Limit Value (TLV) and TLV/420 concentrations, expressed as $\mu\text{g}/\text{m}^3$. The reason for presenting the TLV/420 is that this value is used by many states in air toxic regulations as an annual concentration guideline not to be exceeded. Two additional columns of Table 4.4-9 present "typical" state toxic guidelines, both for short-term (1- to 24-hour) and annual averages. There is a great deal of variability in air toxic guideline concentrations from state to state, sometimes by large factors. Therefore, in order to determine typical values, the median of all NATICH listed values was selected.

The highest CMP and Basin F metals concentrations for the remediation period and post-remediation period were then compared to the appropriate guideline values. For example, 24-hour sample results

were compared to the 24-hour guideline, and the long-term average values of the monitoring period were compared to the annual guideline. This is a conservative approach, as most of the sample days in the CMP and Basin F database were based on high event, or worst-case scenarios. The last two columns of Table 4.4-9 show the percentage of the highest CMP and Basin F program maximum 24-hour and average metals concentrations to the guidelines. It can be seen that all metals results were well below levels of concern with the possible exception of chromium. Chromium maximum levels, however, decreased significantly during the post-remedial Phase 3 and Phase 4 periods.

Chromium results indicate a 24-hour maximum concentration of $0.2858 \mu\text{g}/\text{m}^3$, which was 57 percent of the typical guideline value; the long-term average value was $0.0200 \mu\text{g}/\text{m}^3$, or 20 percent of the annual guideline. However, these levels resulted mainly from the one maximum 24-hour measurement at BF4 during Phase 1. All other maximum chromium measurements at Basin F were considerably lower. The second highest chromium measurement was $0.2083 \mu\text{g}/\text{m}^3$ at BF3, 42 percent of the short-term guideline. Chromium decreased with distance from Basin F, with minimal or no detections during Phases 3 and 4.

Basin F appeared to be a localized source of copper and zinc. The short-term maximum copper level of $1.4980 \mu\text{g}/\text{m}^3$ was 15 percent of the mean 24-hour typical guideline, while the short-term maximum level of $3.3576 \mu\text{g}/\text{m}^3$ for zinc was 1.8 percent of the guideline. These levels occurred at BF2 and BF5 during Phase 1 and Phase 2, Stage 1. Annual averages for copper and zinc were 2 percent and 11 percent of the annual guideline, respectively. During Phase 3 and Phase 4, copper and zinc levels dropped to less than 2 percent of the 24-hour and annual guidelines.

The maximum 24-hour cadmium measurement was at the southern perimeter of the Arsenal at AQ5, $0.0281 \mu\text{g}/\text{m}^3$, and was 7 percent of the short-term guideline. The maximum long-term average at FC2, $0.0027 \mu\text{g}/\text{m}^3$, was 3 percent of the annual guideline. A cadmium source appeared to be off the Arsenal, although slightly higher cadmium concentrations occurred in the vicinity of Basin F during the post-remedial period.

Arsenic was measured at highest levels at AQ2 and AQ5 during Phases 1 and 2. However, maximum short-term and long-term averages were 1 percent and 2 percent of the respective typical 24-hour and annual guidelines. During Phases 3 and 4, maximum arsenic levels were less than 1 percent of the 24-hour and annual guidelines.

Lead, which is an EPA criteria pollutant, has been a source of concern in the metropolitan Denver area in the past. There is an apparent influx of lead into the Arsenal area from Denver. However, the maximum average level measured at AQ7 (during FY89), near the southwest boundary of RMA, was $0.0573 \mu\text{g}/\text{m}^3$, or 4 percent of the Colorado monthly average standard of $1.5 \mu\text{g}/\text{m}^3$.

The maximum 24-hour mercury measurement of $7.3 \mu\text{g}/\text{m}^3$ was at BF2 during Phase 1, and was 15 percent of the typical guideline. The highest long-term average for mercury, $1.8 \mu\text{g}/\text{m}^3$, was also measured at BF2 during the Phase 1 period.

4.4.6 SUMMARY

Ambient metals concentrations distributed across RMA were generally proportional to TSP concentrations. Relatively high metals concentrations were associated with strong and gusty winds; however, there were many exceptions on a day-by-day basis. The extreme maxima were associated with poor dispersion conditions and light winds during winter and occurred on days with high particulate levels over Denver. Basin F appeared to be a potential source of chromium, mercury, copper and zinc during Phase 1 remedial activities, but concentrations were localized and decreased rapidly with distance from the source. After remediation, metals levels in the vicinity of Basin F were typical of RMA baseline concentrations. None of the metals measured during the CMP high event days nor the Basin F monitoring program indicate significant toxic or contamination levels.

4.5 ASBESTOS

Asbestos sampling was conducted at four sites for FY90 in accord with the locations and schedule described in Table 4.5-1. Sites were selected in the vicinity of asbestos sources within RMA and to maintain continuity with previous monitoring. Since asbestos detections were minimal in CMP FY88 and FY89, monitoring was reduced to monthly sampling rather than every 12 days beginning in February, 1990.

Table 4.5-1 Synopsis of FY90 Asbestos Monitoring

Station	Number of Samples	Percent of Recovery
AQ1	18	100
AQ6	17	100
AQ8	18	94
AQ12	18	100
Program Total	71	98

A minimum detectable level of 7 fibers/mm² (which for target volumes is equivalent to less than 0.001 fibers/ml) was established for the laboratory sample analyses. Concentrations were determined by dividing the observed counts by the fractional area observed and by the sample volume. All the samples collected during FY90 had counts below the minimum detection limit. It is evident that asbestos concentrations were below significant levels in the general ambient confines of RMA.

4.6 VOLATILE ORGANIC COMPOUNDS (VOCs)

4.6.1 CMP VOC SAMPLING, ANALYSIS AND REPORTING STRATEGIES

The CMP Technical Plan calls for VOC seasonal monitoring at four RMA perimeter sites during the spring, fall and winter periods, and six high event sampling episodes to be conducted at four perimeter sites and four mobile sites during specified meteorological criteria as outlined previously in Table 3.2-2.

VOC monitoring was initiated under the CMP FY88 program after laboratory certification methods were approved. VOC sampling continued through FY90 with little change in the basic program. As indicated in the FY88 and FY89 reports, low VOC certification ranges frequently resulted in values above the certification limit. Several adjustments were made to the air program, including lowering the sampler flow rate significantly. It was anticipated that the termination of Basin F cleanup activities would further reduce concentrations. Nevertheless, FY90 results continued to be above the

detection limits for certain analytes. As in the past two years, the analytical laboratory estimated VOC target analyte levels that were above the certified reporting limit using methods of retrieval discussed in Section 8.0. Actions have been established to raise the upper range of the certification detection limits in FY91.

The fact that certain target analytes were measured and analyzed above certification limits is a reflection of the limited certification ranges and does not necessarily imply that these levels represent potential contamination risks. The available data, in fact, reflect the contrary. This is especially substantiated by the more extensive IRA-F Monitoring Program database that has been incorporated into the report. The data listings of all CMP VOCs collected during FY90 are provided in Appendix E. In this section, all of the sample results are summarized and evaluated, and data above certified reporting limits were incorporated into the analysis.

Emphasis during the CMP FY90 Program was placed on: (1) four fixed perimeter sites to establish a long-term database and to evaluate potential Arsenal and off-Arsenal VOC impacts at RMA boundaries; and (2) four or more interior RMA mobile sites to measure potential Arsenal internal source impacts. Because of the intense Basin F remedial activity during FY88, CMP VOC sampling was centered around Basin F and was supplemented by more intensive Basin F Remedial Monitoring Program sampling in order to establish a viable database for remedial assessment. During FY89 and FY90, the follow-on IRA-F Monitoring Program continued an intensive monitoring effort around Basin F. These results will be discussed in Section 4.6.3.2. The CMP FY90 VOC program not only included monitoring of Basin F sites, but also Basin A, Basin A Neck, the South Plants, the South Plants subdrain area, and RMA perimeter sites in order to establish a broader background of VOC levels across the Arsenal and at future projected remedial locations. CMP FY90 results will be discussed in Section 4.6.2. Combined Basin F and CMP VOC results will be discussed in Section 4.6.3.3 and will include FY88, FY89, and FY90 data obtained during the four phases of the remedial assessment programs which are outlined in Table 4.1-1.

As noted previously, CMP VOC monitoring consisted of seasonal monitoring and high event (mostly summertime) monitoring when VOCs are likely to be most prevalent. For the most part, all high event monitoring met the specified meteorological criteria of temperatures in excess of 75° F at the start of the monitoring period. Since the wind criteria of less than 5 mph was extremely difficult to predict during the summer seasons, especially during mid-afternoon when convective activity was at its highest levels, emphasis as in the past was placed on mobilizing for light wind days, generally

between 5 and 8 mph. Because of the variability of light winds, each high event monitoring episode concentrated on a particular potential source with several samplers surrounding the source area.

Experience gained in the CMP FY88 and FY89 programs also formed the basis for modifications and improvements to the FY90 high event program. Although the VOC high event monitoring was initiated on very warm days with temperatures in excess of 75° F, the monitoring was generally continued through the 24-hour period in order to capture the impacts of volatile organic compounds released under the warm temperatures and then trapped under inversion conditions. The Basin F and CMP monitoring strategies strongly complemented each other, and provided patterns for assessing impacts under variable conditions relating to wind flow, temperature ranges, air quality dispersion, source activity and diurnal influences.

4.6.2 CMP FY90 VOC MONITORING RESULTS

VOCs were monitored in FY90 for seasonal and high event conditions as presented in Table 4.6-1. Table 4.6-2 shows a summary of results of the sampling of 22 target VOCs at various fixed and mobile locations across RMA. The tables indicate the annual average and 24-hour maximum levels at each site.

It should be noted that seasonal sampling was conducted under fall, winter and spring conditions and all high event sampling episodes were conducted in the summer season to meet high event criteria. Levels were comparable to CMP FY88 and FY89 results outside the range of Basin F impacts, with several exceptions. Higher average concentrations of 1,1,1-trichloroethane were reported at most stations than in the previous 2 years. The highest maximum 24-hour value was 7.161 $\mu\text{g}/\text{m}^3$ at AQ5 near the southern boundary of the Arsenal. Carbon tetrachloride was measured at moderately high concentrations in the South Plants area. Chloroform and methylene chloride were also measured at higher levels in the South Plants. Several analytes including ethylbenzene, toluene, methylisobutylketone, tetrachloroethene, and xylene were reported with higher average values during FY90 at perimeter stations, in particular, at AQ1, on the west, and at AQ5 on the southern Arsenal boundary.

Table 4.6-1 Synopsis of FY90 Monitoring for Volatile Organic Compounds (VOC)

Date	Period (24-Hours)	Site Locations
December 19, 1989*	1500 - 1500	AQ1, AQ3, AQ4, AQ5, AQ5C
March 16, 1990*	1230 - 1230	AQ1, AQ3, AQ4, AQ5, AQ5C
May 21, 1990*	1100 - 1100	AQ1, AQ2, AQ3, AQ5, AQ5C
June 27, 1990	0700 - 0700	AQ1, AQ3, AQ4, AQ5, AQ5C, Mobile 1, Mobile 2, Mobile 3, Mobile 4
June 28, 1990	0900 - 0900	AQ1, AQ3, AQ4, AQ5, AQ5C, Mobile 1, Mobile 2, Mobile 3, Mobile 4
July 18, 1990	0900 - 0900	AQ1, AQ3, AQ4, AQ5, AQ5C, FC2, FC3, FC5, Mobile SE
July 27, 1990	1000 - 1000	AQ1, AQ3, AQ4, AQ5, AQ5C, AQ10, AQN, AQW, AQS
August 2, 1990	0800 - 0800	AQ1, AQ3, AQ4, AQ5, AQ5C, FC2, FC3, FC4, FC5
August 9, 1990	0900 - 0900	AQ1, AQ3, AQ4, AQ5, AQ5C, AQ8, AQ9, Mobile E, Mobile W
September 11, 1990	0800 - 0800	AQ6, AQ10, AQ10C, Mobile E, Mobile W

* Seasonal monitoring; all others were high event monitoring cases.

Several VOC target analytes including benzene, chloroform, ethylbenzene, toluene, and dimethyldisulfide were previously identified as potential emissions from Basin F and were reported at lower values at the Basin F stations during FY90. There was a shift in high VOC concentrations during FY90 from the Basin F area to the Arsenal perimeter, reflecting urban impacts across the area. Average and 24-hour maximum concentrations of chloroform, ethylbenzene, toluene, methylisobutylketone, dimethylbenzene, tetrachloroethene, and xylene were measured at AQ1 on the western perimeter of the Arsenal closest to metropolitan Denver influences. Other analytes including chloroform, carbon tetrachloride, and methylene chloride were measured at higher concentrations in the vicinity of Basin A and the South Plants, where new remedial tasks were initiated.

Table 4.6-2 Summary of FY90 Volatile Organic Compound (VOC) Concentrations (in $\mu\text{g}/\text{m}^3$)

	111TCE	112TCE	DCLE11	DCLE12	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
AQ1	2.197	*	*	0.054	*	3.081	0.559	5.518	0.169	*	*
AQ2	0.996	*	*	0.061	*	1.378	0.337	3.214	0.037	*	*
AQ3	1.801	*	*	0.073	*	1.548	0.493	3.620	0.180	*	*
AQ4	1.603	*	*	0.047	*	1.761	0.505	4.358	0.093	*	*
AQ5	3.225	*	*	0.080	*	2.563	0.527	4.696	0.093	*	*
AQ6	4.044	*	*	*	*	1.865	0.366	5.873	0.171	*	*
AQ8	3.073	*	*	*	1.081	3.307	0.390	13.225	9.653	*	*
AQ9	2.576	*	*	*	*	2.851	0.392	13.299	0.330	*	*
AQ10	3.066	*	*	0.055	*	1.413	0.388	10.573	0.226	*	*
AQ01	1.514	*	*	0.027	0.195	1.324	0.322	2.424	0.313	0.027	*
AQ02	4.115	*	*	*	*	1.898	0.337	13.281	0.208	*	*
AQ23	2.305	*	*	0.089	*	1.415	0.585	7.578	0.584	*	*
AQ26	2.132	*	*	0.095	*	1.573	0.510	6.401	0.365	*	*
AQ35	1.323	*	*	0.097	*	1.220	0.401	1.372	0.080	*	*
AQ36	2.554	*	*	*	0.150	1.180	1.357	13.189	1.679	*	*

AVERAGE VALUES

* All values below CRL

Legend: 111TCE 1,1,1-Trichloroethane
 112TCE 1,1,2-Trichloroethane
 DCLE11 1,1-Dichloroethane
 DCLE12 1,2-Dichloroethane
 BCHPD Bicycloheptadiene
 C6H6 Benzene
 CCL4 Carbon Tetrachloride
 CH2CL2 Methylene Chloride
 CHCL3 Chloroform
 CLC6H5 Chlorobenzene
 DBCP Dibromochloropropane

Table 4.6-2 Summary of FY90 Volatile Organic Compound (VOC) Concentrations (in $\mu\text{g}/\text{m}^3$) (continued)

	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	DMB12	T12DCE	TCLEE	TRCLE	XYLENE
	AVERAGE VALUES										
AQ1	*	*	1.382	9.228	0.257	*	1.818	*	1.658	0.141	3.881
AQ2	*	*	0.438	5.469	*	*	0.485	*	1.293	*	1.288
AQ3	*	*	0.627	4.459	0.103	*	0.813	*	0.918	0.078	2.544
AQ4	*	*	0.652	5.969	0.078	*	0.851	*	0.718	0.054	1.604
AQ5	*	*	1.011	8.109	0.173	*	1.344	*	2.389	0.093	2.955
AQ6	*	*	0.222	5.553	0.160	*	0.271	*	0.656	0.138	0.872
AQ8	*	*	0.450	11.254	*	*	0.499	*	0.665	0.199	3.533
AQ9	*	*	0.385	5.639	*	*	0.502	*	0.669	0.140	1.777
AQ10	*	*	0.313	5.321	0.201	*	0.352	*	0.662	0.098	1.009
AQ01	0.053	*	0.417	9.162	0.114	*	0.604	*	1.166	0.055	1.484
AQ02	*	*	0.452	5.651	0.251	*	0.501	*	1.336	0.124	1.331
AQ23	*	*	0.371	7.036	*	*	0.496	*	0.664	0.165	1.103
AQ26	*	*	0.311	5.340	*	*	0.553	*	0.869	0.064	1.246
AQ35	*	*	0.451	3.490	*	*	0.518	*	0.676	*	1.374
AQ36	*	*	0.411	8.394	*	*	0.745	*	0.663	0.336	2.850

* All values below CRL

Legend: DCPD Dicyclopentadiene
 DMDS Dimethyl disulfide
 ETC6H5 Ethylbenzene
 MEC6H5 Toluene
 MIBK Methylisobutylketone
 NNDMEA N-Nitrosodimethylamine
 DMB12 Dimethylbenzene
 T12DCE Trans-1,2-Dichloroethene
 TCLEE Tetrachloroethene
 TRCLE Trichloroethene
 XYLENE Xylene

Table 4.6-2 Summary of FY90 Volatile Organic Compound (VOC) Concentrations (in $\mu\text{g}/\text{m}^3$) (continued)

	111TCE	112TCE	DCLE11	DCLE12	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
24-HOUR MAXIMUM VALUES											
AQ1	5.020	*	*	0.118	*	4.751	1.147	19.809	0.478	*	*
AQ2	0.996	*	*	0.061	*	1.378	0.337	3.214	0.037	*	*
AQ3	3.963	*	*	0.155	*	2.900	0.993	13.243	0.444	*	*
AQ4	3.521	*	*	0.090	*	4.640	0.995	13.960	0.274	*	*
AQ5	7.161	*	*	0.178	*	7.548	1.169	13.262	0.214	*	*
AQ6	4.044	*	*	*	*	1.865	0.366	5.873	0.171	*	*
AQ8	3.073	*	*	*	1.081	3.307	0.390	13.225	9.653	*	*
AQ9	2.576	*	*	*	*	2.851	0.392	13.299	0.330	*	*
AQ10	4.610	*	*	0.095	*	1.890	0.390	19.837	0.285	*	*
AQ01	4.571	*	*	0.052	0.541	1.874	0.397	13.114	0.698	0.046	*
AQ02	4.115	*	*	*	*	1.898	0.337	13.281	0.208	*	*
AQ23	3.591	*	*	0.163	*	1.419	0.781	13.169	0.967	*	*
AQ26	4.616	*	*	0.168	*	3.761	0.781	13.243	0.486	*	*
AQ35	1.562	*	*	0.102	*	1.441	0.404	1.399	0.083	*	*
AQ36	2.576	*	*	*	0.267	1.425	1.929	13.299	2.386	*	*

* All values below CRL

Legend: 111TCE 1,1,1-Trichloroethane
 112TCE 1,1,2-Trichloroethane
 DCLE11 1,1-Dichloroethane
 DCLE12 1,2-Dichloroethane
 BCHPD Bicycloheptadiene
 C6H6 Benzene
 CCL4 Carbon Tetrachloride
 CH2CL2 Methylene Chloride
 CHCL3 Chloroform
 CLC6H5 Chlorobenzene
 DBCP Dibromochloropropane

Table 4.6-2 Summary of FY90 Volatile Organic Compound (VOC) Concentrations (in $\mu\text{g}/\text{m}^3$) (continued)

	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	DMB12	T12DCE	TCLEE	TRCLE	XYLENE
	24-HOUR MAXIMUM VALUES										
AQ1	*	*	5.294	16.881	1.045	*	5.870	*	4.627	0.295	9.523
AQ2	*	*	0.438	5.469	*	*	0.485	*	1.293	*	1.288
AQ3	*	*	3.086	11.254	0.449	*	3.519	*	2.931	0.195	9.036
AQ4	*	*	2.962	11.479	0.546	*	3.431	*	2.286	0.148	5.205
AQ5	*	*	3.776	16.693	0.694	*	4.934	*	5.894	0.316	8.380
AQ6	*	*	0.222	5.553	0.160	*	0.271	*	0.656	0.135	0.872
AQ8	*	*	0.450	11.254	*	*	0.499	*	0.665	0.199	3.533
AQ9	*	*	0.385	5.659	*	*	0.502	*	0.669	0.140	1.777
AQ10	*	*	0.446	5.627	0.204	*	0.494	*	0.665	0.156	1.312
AQ01	0.119	*	0.467	11.377	0.280	*	0.987	*	1.978	0.144	1.786
AQ02	*	*	0.452	5.651	0.251	*	0.501	*	1.336	0.124	1.331
AQ23	*	*	0.410	11.270	*	*	0.500	*	0.666	0.290	1.327
AQ26	*	*	0.448	11.270	*	*	1.000	*	1.332	0.118	2.637
AQ35	*	*	0.471	4.003	*	*	0.528	*	0.704	*	1.402
AQ36	*	*	0.418	11.129	*	*	0.987	*	0.669	0.488	4.368

* All values below CRL

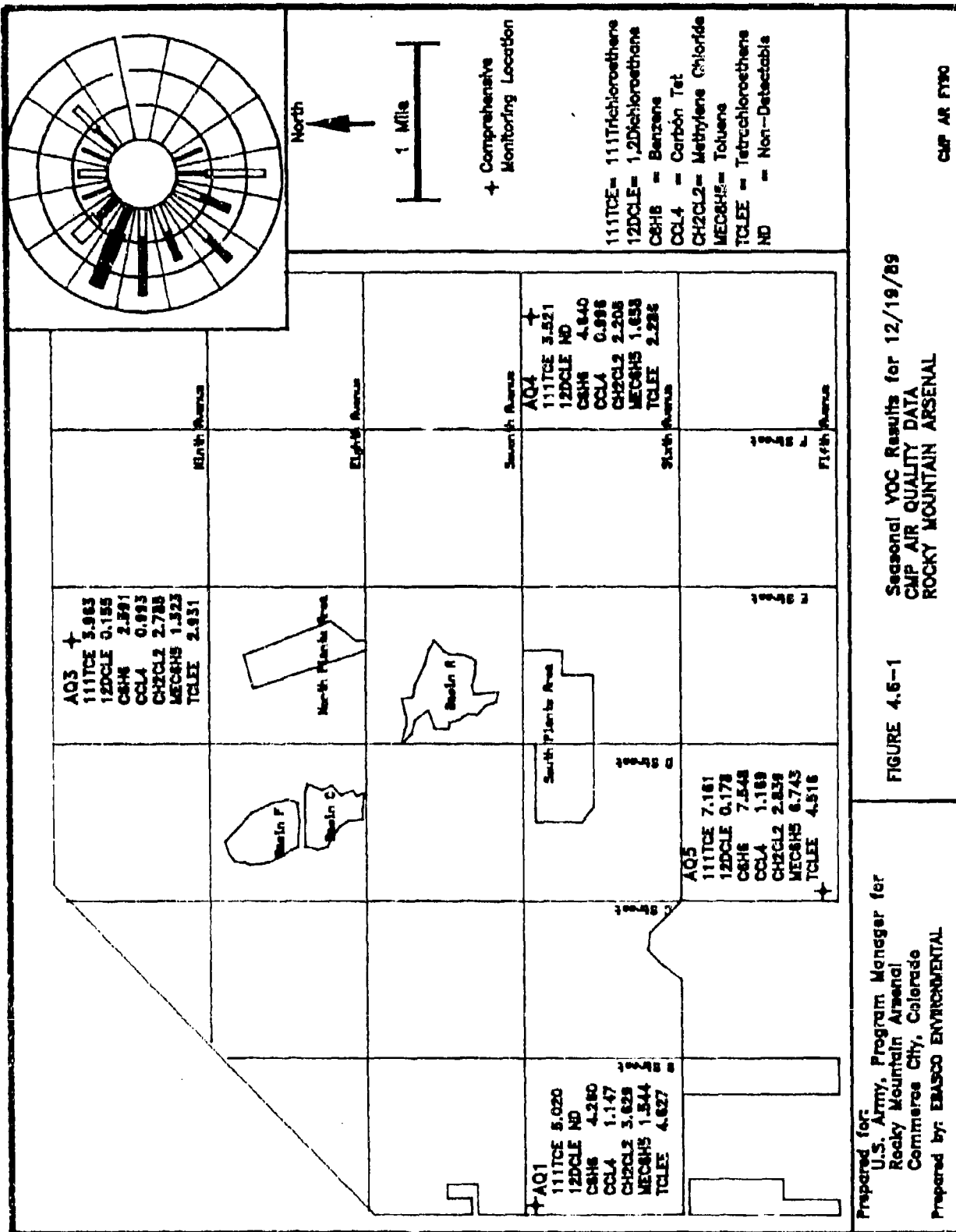
Legend: DCPD Dicyclopentadiene
 DMDS Dimethyl disulfide
 ETC6H5 Ethylbenzene
 MEC6H5 Toluene
 MIBK Methylisobutylketone
 NNDMEA N-Nitrosodimethylamine
 DMB12 Dimethylbenzene
 T12DCE Trans-1,2-Dichloroethene
 TCLEE Tetrachloroethene
 TRCLE Trichloroethene
 XYLENE Xylene

During FY90, high event monitoring was conducted at Basin F, the South Plants, the South Plants subdrain area, Basin A, and the Basin A Neck area. Samples from Basin F monitoring were grouped together and designated as AQ23 and AQ26 in Table 4.6-2, reflecting the section of the Arsenal from which they were collected. All mobile samples taken from RMA Sections 1 and 2, including those collected around the South Plants and South Plants subdrain area, were grouped together and designated in Table 4.6-2 as AQ01 and AQ02. Mobile samples collected in Sections 35 and 36 (Basin A) were grouped together and designated as AQ35 and AQ36. Because VOC levels varied considerably as a result of meteorological dispersion conditions and source characteristics, it was necessary to examine these impacts on an individual daily basis. Several examples are provided below.

4.6.2.1 December 19, 1989

VOCs were monitored under the CMP at four perimeter stations on this date for 24 hours. This was a winter seasonal monitoring event designed to identify the transport of potential toxic pollutants across the Arsenal boundaries. Figure 4.6-1 shows site locations and sampling results for selected compounds, along with a wind rose corresponding to the monitoring period. Winds were from the south through west-northwest with moderate speeds of 5 to 13 mph during the early portion of the monitoring period and gusted to above 20 mph during the last several hours of monitoring. The temperature ranged from a high of 45°F to a low of 7°F. Atmospheric stability ranged from highly stable conditions to neutral conditions during stronger wind periods toward the end of sampling. Stations AQ1 and AQ5 on the western and southern perimeters measured the highest levels for most compounds. With moderate to strong winds primarily from the south through west, these compounds were probably transported from metropolitan Denver urban and industrial sources.

Maximum levels of 1,1,1-trichloroethane ($7.161 \mu\text{g}/\text{m}^3$), 1,2-dichloroethane ($0.178 \mu\text{g}/\text{m}^3$), benzene ($7.548 \mu\text{g}/\text{m}^3$), carbon tetrachloride ($1.169 \mu\text{g}/\text{m}^3$), methylene chloride ($2.839 \mu\text{g}/\text{m}^3$), toluene ($6.743 \mu\text{g}/\text{m}^3$), and tetrachloroethene ($4.516 \mu\text{g}/\text{m}^3$) were measured at AQ5 near the southern Arsenal boundary. At AQ1 on the western boundary, maximum levels of ethylbenzene ($5.294 \mu\text{g}/\text{m}^3$), not shown in the figure, dimethylbenzene ($5.871 \mu\text{g}/\text{m}^3$), and xylene ($9.523 \mu\text{g}/\text{m}^3$) were measured. Levels of VOCs at AQ1 and AQ5 were generally 50 percent or more higher than levels at AQ3 and AC at the northern and eastern Arsenal boundaries further from the urban influence. Levels of 1,1,1-trichloroethane, 1,2-dichloroethane, benzene, ethylbenzene, toluene, dimethylbenzene, methylisobutylketone, tetrachloroethene, and xylene on this date were the highest 24-hour values recorded during the FY90 monitoring period. This was a typical winter day with several hours of inversion conditions followed by moderate winds blowing from the metropolitan area toward the



Prepared for: U.S. Army, Program Manager for Rocky Mountain Arsenal, Commerce City, Colorado
 Prepared by: EBASCO ENVIRONMENTAL

FIGURE 4.6-1 Seasonal VOC Results for 12/19/89
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AR FY90

Arsenal, substantiating the overriding influence of Denver urban and industrial activity on Arsenal air quality during the Basin F post-remediation period.

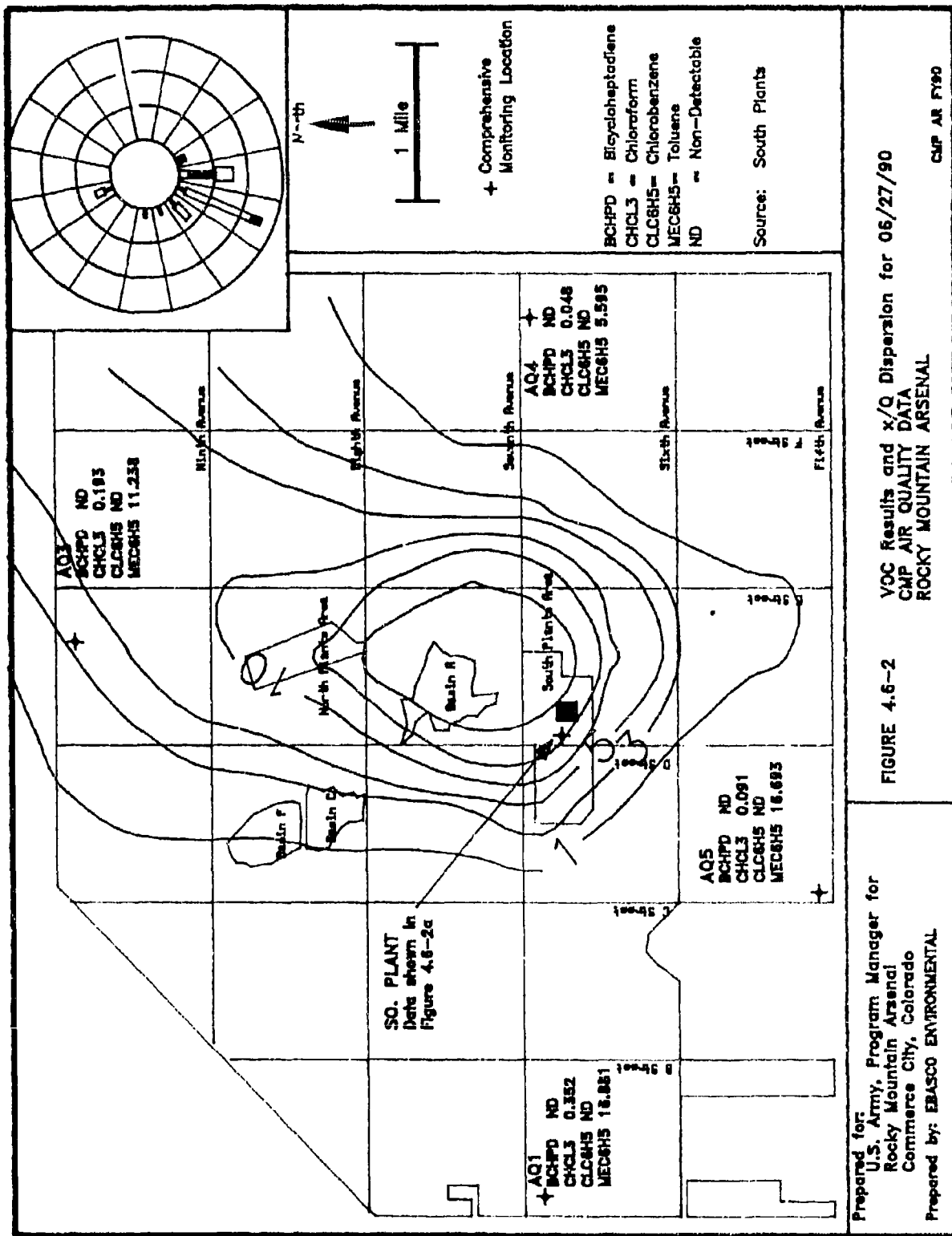
4.6.2.2 June 27, 1990

VOCs were monitored under this CMP high event scenario at four RMA perimeter stations and four mobile stations in the vicinity of the South Plants from 0800 MST on June 27 to 0800 MST on June, 28, 1990. Figures 4.6-2 and 4.6-2a show site locations and sampling results for selected compounds, along with the wind rose for the monitoring period. The maximum temperature on this day was 97°F, with primarily south-southwesterly winds at moderate speeds. Atmospheric stability was unstable during the midday period of June 27 and was neutral to slightly stable through the remainder of the period. Assuming the South Plants was a potential source, the dispersion pattern indicates greater impacts close to the South Plants and along the plume extending to the north-northeast. The data reflect fairly uniform distributions of all VOCs across the South Plants area with the exception of chloroform, which recorded its highest level of $0.484 \mu\text{g}/\text{m}^3$ at the mobile site to the northeast of the South Plants directly in the plume, and the second highest level of $0.410 \mu\text{g}/\text{m}^3$ at the mobile site northwest of the plume. A low bicycloheptadiene level of $0.541 \mu\text{g}/\text{m}^3$ and a chlorobenzene level of $0.046 \mu\text{g}/\text{m}^3$ was also measured at the site just northeast of the South Plants. Moderate levels of toluene ranging from 11.254 to $11.377 \mu\text{g}/\text{m}^3$ were recorded at all four mobile sites; however, toluene levels in excess of $16 \mu\text{g}/\text{m}^3$ were measured on other sampling days in May and June at AQ1 and AQ5. Under prevailing southerly and south-southwesterly wind flow, toluene was probably transported to the Arsenal from urban Denver sources. The highest levels of all other compounds analyzed were detected at AQ1 and AQ5 at the western and southern boundaries of the Arsenal.

On another South Plants high event scenario the following day (not shown here, see Appendix E for data), almost identical results were attained. Chloroform was measured at $0.698 \mu\text{g}/\text{m}^3$ northeast of the South Plants and bicycloheptadiene was measured at $0.534 \mu\text{g}/\text{m}^3$ to the northwest. Chlorobenzene was not detected on this day. All other compounds measured the highest levels at the CMP perimeter sites.

4.6.2.3 July 18, 1990

Under this CMP high event scenario, VOCs were monitored at four RMA perimeter sites and four mobile sites surrounding Basin F from 0900 MST on July 18 to 0900 MST on July 19, 1990. Figure 4.6-3 shows site locations and sampling results for selected compounds, along with the wind rose for



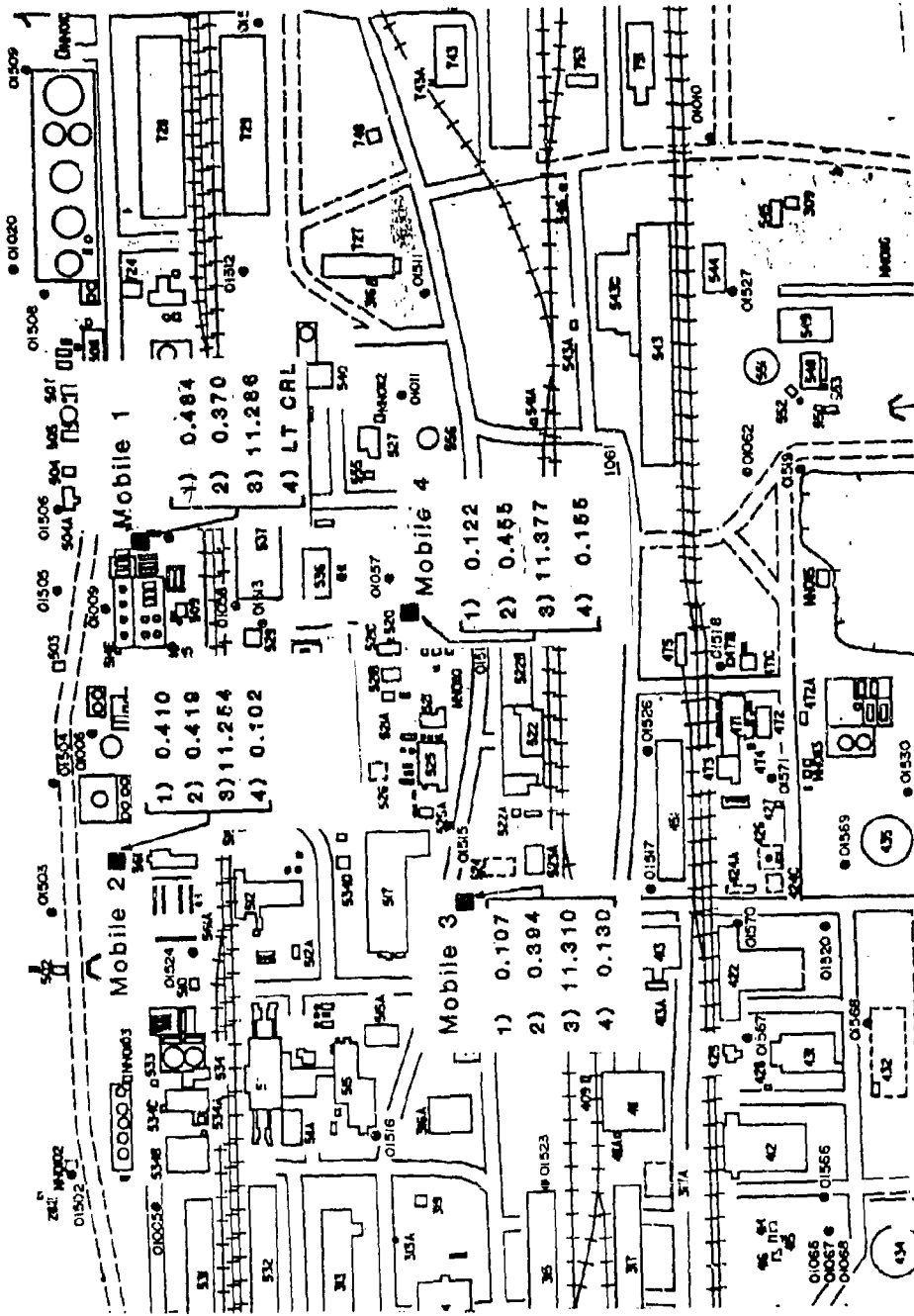


Figure 4.6-2a
VOC Results for 6/27/90
South Plants
CMP AR FY90

Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
R.L. Stellar & Associates, Inc.
Ebasco Services, Inc.

- Legend
- 1) CHCL3
 - 2) ETC6H5
 - 3) MEC6H5
 - 4) MIBK

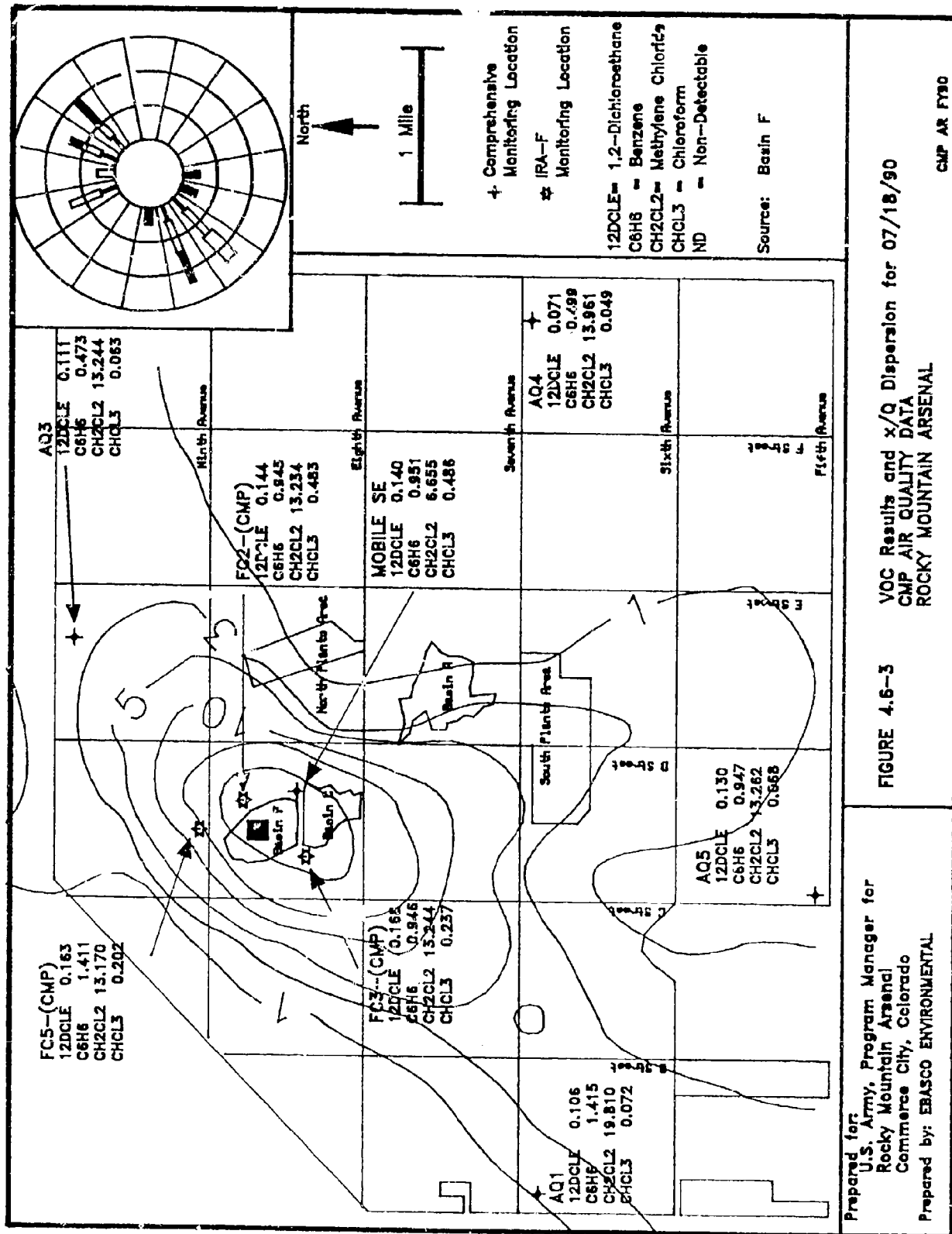


FIGURE 4.6-3 VOC Results and x/Q Dispersion for 07/18/90
CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

Prepared for:
U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by: EBASCO ENVIRONMENTAL

CMP AR FY90

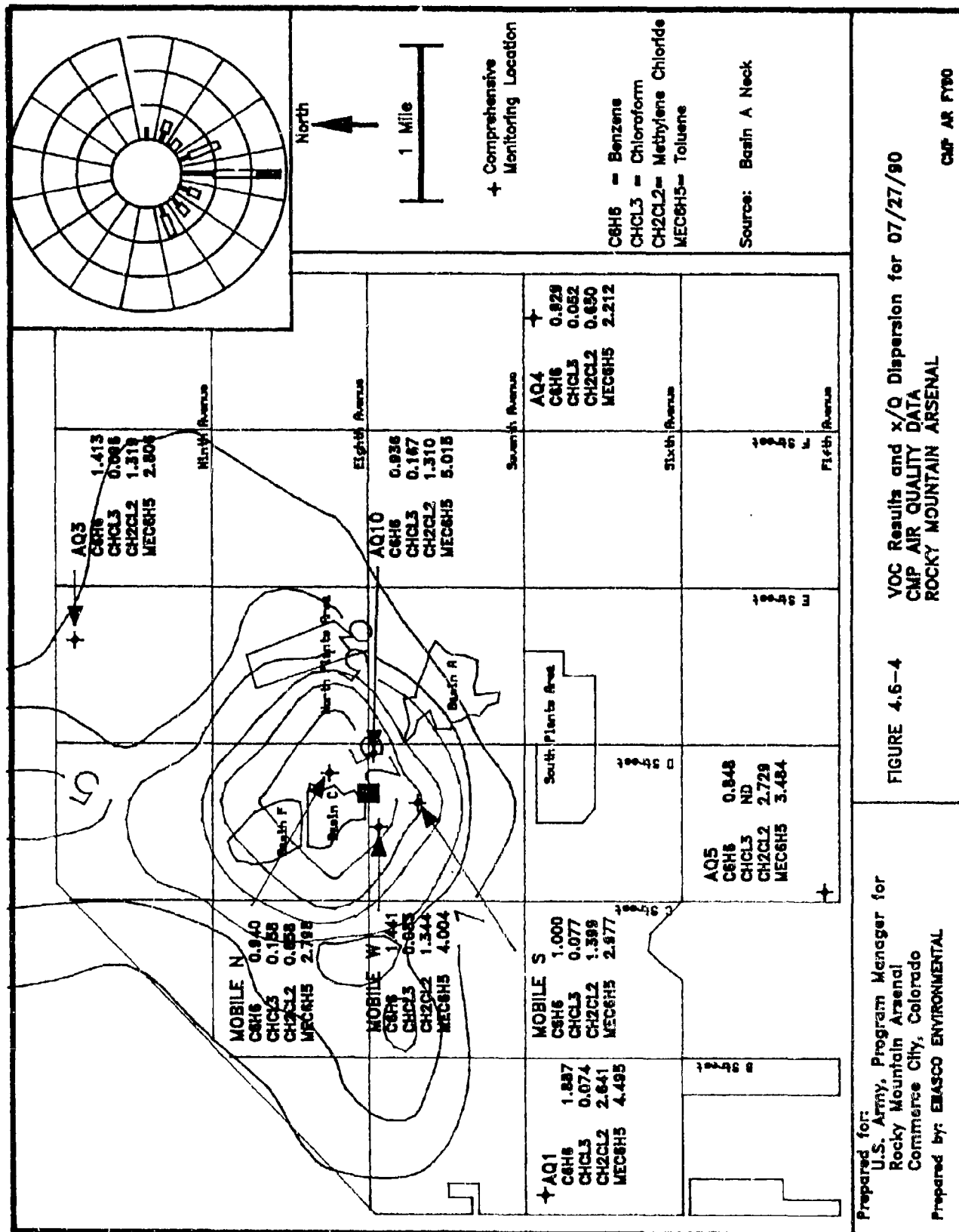
the monitoring period. The maximum temperature on this day was 93°F, with winds primarily from the southwest and the northeast at moderate speeds. Atmospheric stability was unstable during the late morning hours, became neutral with stronger winds during the late afternoon and evening, and was stable under lighter winds after midnight.

Assuming the Basin F post-remedial area was a potential VOC source, the dispersion pattern indicates greater impacts closer to Basin F and along the bimodal plume to the northeast and southwest of the former Basin. Data results, however, showed fairly uniform gradients across the Basin F area with the exception of chloroform, which measured 0.483 $\mu\text{g}/\text{m}^3$ directly northeast of the Basin and 0.486 $\mu\text{g}/\text{m}^3$ just southeast of the Basin. Moderate levels of 1,2-dichloroethane were also measured at all four mobile sites with a high value of 0.168 $\mu\text{g}/\text{m}^3$ reported in the southwest corner of the Basin F area. Benzene was reported at 1.411 $\mu\text{g}/\text{m}^3$ north of the Basin; this value, however, was equivalent to those measured at AQ1 and AQ5 at the Arsenal perimeter. Methylene chloride was also measured at three Basin F sites and ranged from 13.170 to 13.244 $\mu\text{g}/\text{m}^3$, equivalent to values at perimeter sites, with the highest value of 19.810 $\mu\text{g}/\text{m}^3$ measured at AQ1. Again, the perimeter sites closest to the western and southern boundaries measured the highest values for most compounds.

A second high event Basin F monitoring day on August 8, 1990, showed similar results (not shown here, see Appendix E for data). Chloroform and 1,1,1-trichloroethane were measured at their highest levels in the Basin F area. It was difficult to identify any significant VOC emissions from Basin F using these data. More definitive post-remedial monitoring results from the IRA-F program are provided in Section 4.6.3.2. At waste pile vents, the analyte with maximum emissions was chloroform. Emissions from waste pile vents are the likely source of observed chloroform levels.

4.6.2.4 July 27, 1990

VOCs were monitored under this CMP high event scenario at four RMA perimeter sites and four mobile sites surrounding the Basin A Neck excavation activities. Figure 4.6-4 shows site locations and sampling results for selected compounds along with a wind rose for the monitoring period, which began at 1000 MST on July 27 and ended at 1000 MST on July 28, 1990. The maximum temperature on this day was 84°F. Wind directions were primarily from the south with light to moderate wind speeds, averaging 4 to 13 mph. Atmospheric stability was slightly unstable throughout most of the midday period and became stable during the early morning period.



Prepared for:
U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by: EIASCO ENVIRONMENTAL

FIGURE 4.6-4

VOC Results and x/Q Dispersion for 07/27/90
CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

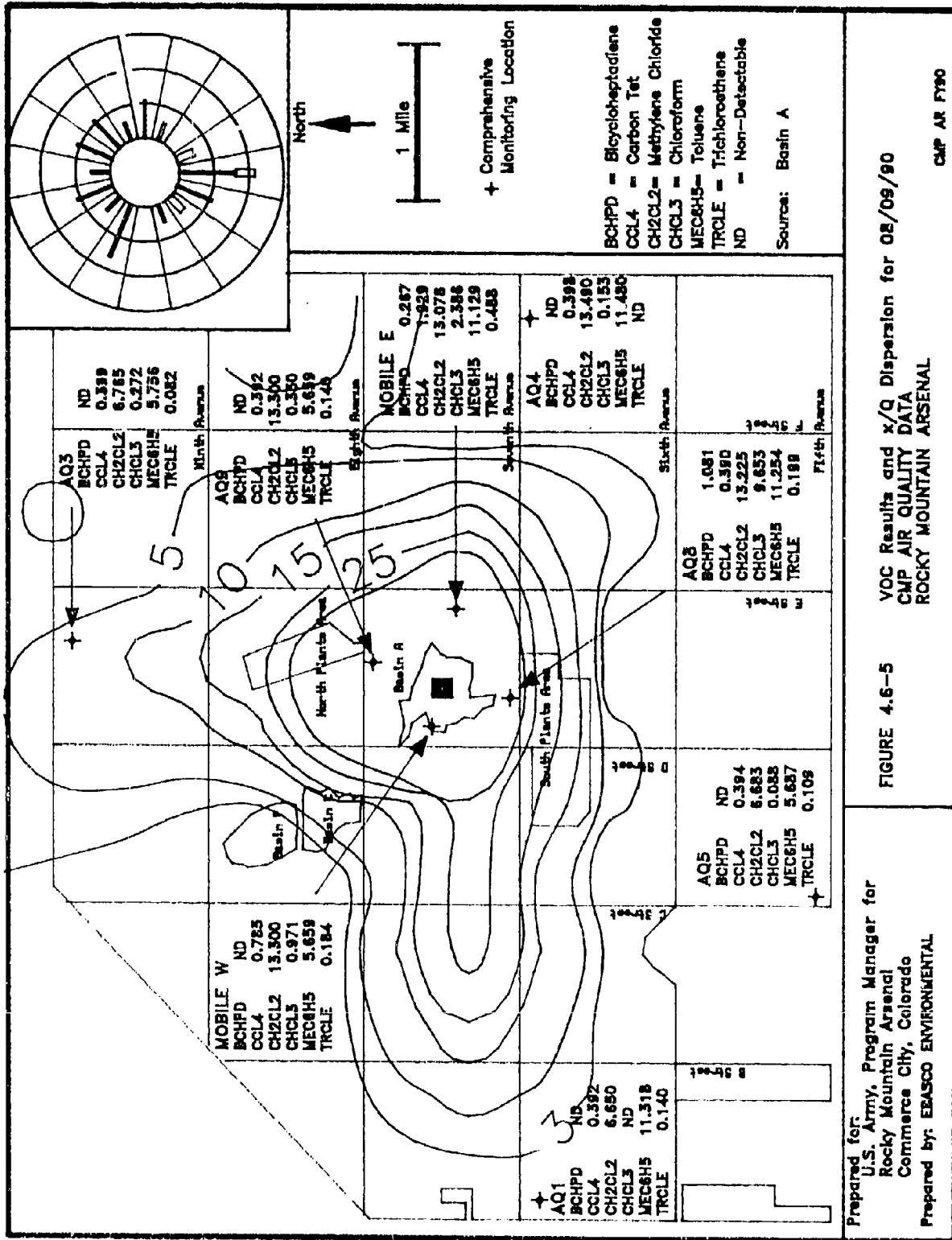
CMP AIR FY90

Assuming the Basin A Neck excavation area was a potential source of VOC emissions, the dispersion pattern shown in Figure 4.6-4 indicates maximum impacts close to the Basin A Neck and along the plume to the north. The data, however, indicate fairly uniform gradients across the Neck area with maximum concentrations for most compounds at the RMA perimeter sites. Exceptions were the higher levels of chloroform at two mobile sites north and west of the excavation activities, where the maximum level reached $0.167 \mu\text{g}/\text{m}^3$. There were also higher toluene levels of $5.015 \mu\text{g}/\text{m}^3$ east of the Neck area and $4.004 \mu\text{g}/\text{m}^3$ to the west. Based on data from this high event episode, Basin A Neck was not a significant source of VOCs.

4.6.2.5 August 9, 1990

VOCs were monitored under this high event scenario at four RMA perimeter sites and four additional stations surrounding the Basin A area, including AQ8 to the south, AQ9 to the north, and two mobile sites east and west of the Basin. Monitoring was conducted for a 24-hour period beginning at 0900 MST on August, 1990. Figure 4.6-5 shows site locations and sampling results for selected compounds, along with a wind rose corresponding to the monitoring period. The maximum temperature on this day was 87°F , with variable winds primarily from the south. Wind speeds were generally light, ranging from 3 to 9 mph. Atmospheric stability was unstable during the midday period and stable during the evening and early morning hours, typical for this season of the year.

Assuming that Basin A was a potential source of VOCs, the dispersion pattern for this day shows highest impacts in close proximity to Basin A and decreasing with distance from the Basin. Although the perimeter sites indicated the highest levels for most compounds, suggesting that Basin A was not a source of these compounds, several maximum VOC levels were measured at sites surrounding the Basin. These included a bicycloheptadiene value of $1.081 \mu\text{g}/\text{m}^3$ at AQ8 south of Basin A, carbon tetrachloride of $1.929 \mu\text{g}/\text{m}^3$ at the mobile site to the east and $0.785 \mu\text{g}/\text{m}^3$ at the mobile site to the west. Methylene chloride ranged from 13.078 to $13.490 \mu\text{g}/\text{m}^3$ at all four Basin A sites as well as AQ4, chloroform was $9.653 \mu\text{g}/\text{m}^3$ at AQ8 to the south, and trichloroethene was $0.488 \mu\text{g}/\text{m}^3$ at the mobile site east of Basin A. A toluene concentration of $11.254 \mu\text{g}/\text{m}^3$ was measured at AQ8, although higher values were recorded at the RMA boundaries. These compounds may be indigenous to the Basin A area; however, there were no consistent patterns across the Basin for each of the compounds. The high levels may have resulted from other Arsenal sources; for example, with prevailing southerly winds, higher concentrations of several analytes may have resulted from a South Plants source. On the other hand these ambient concentrations may have resulted from sources external to the Arsenal. Section 4.6.4.2 illustrates the large number of urban VOC sources surrounding the Arsenal.



Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: EBASCO ENVIRONMENTAL

FIGURE 4.6-5

VOC Results and x/Q Dispersion for 08/09/90
 CNP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CNP AR P190

4.6.2.6 September 11, 1990

High event monitoring on this date near the South Plants subdrain activity indicated generally low levels of all VOCs, with the exception of methylene chloride. A maximum concentration of 19.837 $\mu\text{g}/\text{m}^3$ was recorded at AQ10, the mobile site in the subdrain area. Site locations and monitoring results for this event are shown in Figure 4.6-6, along with a wind rose for the period.

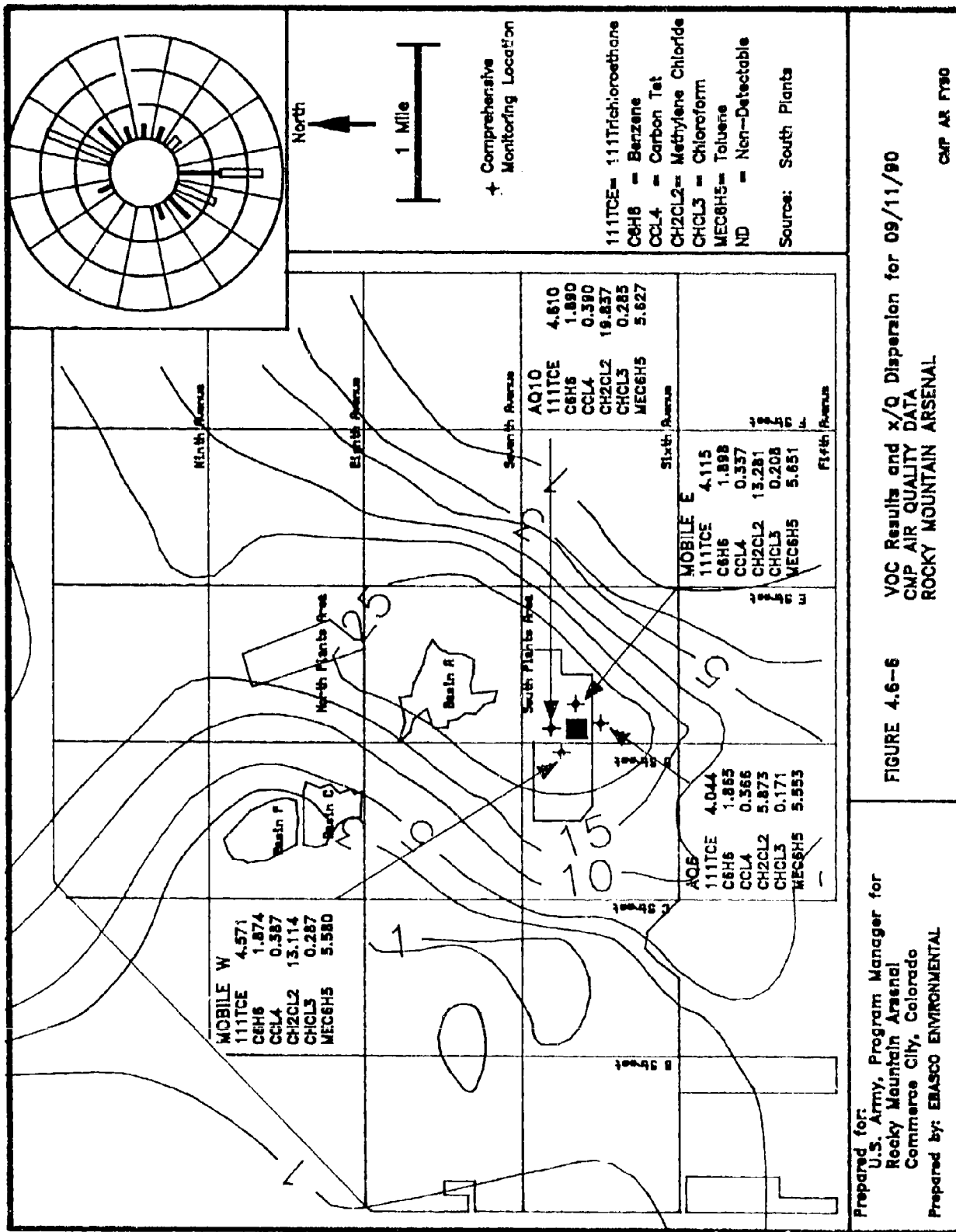
4.6.3 BASIN F VOC IMPACTS

In order to fully evaluate remedial impacts from the Basin F cleanup operations, it was necessary to consider all CMP, Basin F Remedial Monitoring Program and IRA-F data for the remedial and post-remedial periods.

4.6.3.1 CMP Data

CMP FY90 VOC results were discussed in the previous section. Table 4.6-3 incorporates CMP FY88, FY89, and FY90 data and stratifies results for the Phase 1 and Phase 2 remediation periods and the Phase 3 and Phase 4 post-remedial periods. The VOC CMP data show variations across the Arsenal during the separate phases of evaluation. It should be noted that these variations can be a function of meteorological conditions, seasonal impacts and source characteristics. Nevertheless, with the exceptions discussed in Section 4.6.2, VOC target element variations outside the immediate vicinity of Basin F remediation activities were generally at comparable levels during each phase of the 31-month monitoring period. Variations were also apparent at CMP Basin F monitoring locations. Several target compounds that were previously identified in the FY88 report as potential contaminants emitted from the Basin F source and associated remediation activity were noticeably reduced during the FY90 Phase 4 period. These include benzene, chloroform, ethylbenzene, toluene and dimethyl disulfide. It should be noted that because of the mobile nature of the FY90 monitoring program, Basin F stations previously shown as CMP/BF1 through CMP/BF4 in Phases 1, 2 and 3 were grouped as AQ23 and AQ26 in the Phase 4 period.

The emphasis in the CMP has been to provide a broad pattern of baseline air quality conditions at Arsenal remediation locations, interior locations, and perimeter sites. Because of the more intense monitoring efforts under the Basin F Remedial Monitoring and IRA-F programs, the CMP effort has been to supplement and confirm data collected from the other programs. Nevertheless, CMP results for FY88, FY89, and FY90 have been consistent with Basin F results. Much more detailed and



Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: ERASCO ENVIRONMENTAL

FIGURE 4.6-6

VOC Results and x/Q Dispersion for 09/11/90
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AR FY90

Table 4.6-3 Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)

	111TCE	112TCE	DCLE11	DCLE12	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
AVERAGE VALUES											
PHASE 1											
AQ1	0.987	*	*	0.053	*	2.659	0.417	1.890	0.336	0.086	*
AQ2	2.450	*	*	*	*	4.282	0.354	3.995	0.365	*	*
AQ3	0.875	*	*	0.058	0.121	2.192	0.362	0.971	0.159	*	*
AQ4	1.112	*	*	0.135	*	4.349	0.858	1.614	0.823	*	*
AQ5	1.840	*	*	*	*	2.465	0.456	3.287	0.193	*	*
AQ8	0.378	*	*	*	*	2.907	0.288	0.635	6.010	*	*
AQ9	0.842	*	*	*	*	1.569	0.525	0.967	0.162	*	*
AQ01	0.822	*	*	0.044	*	1.353	0.407	1.715	1.158	0.097	*
AQ36	0.460	*	*	*	*	0.534	0.360	0.673	0.556	*	*
CMP/BF1	0.822	*	*	*	*	10.532	0.324	0.818	0.268	0.324	0.148
CMP/BF2	0.837	*	0.040	*	2.675	3.007	0.395	4.744	3.031	0.472	2.902
CMP/BF3	1.059	*	0.139	0.041	*	2.679	0.660	0.637	0.345	*	*
CMP/BF4	0.533	*	*	*	*	1.427	0.378	0.605	0.427	*	*
PHASE 2 - STAGE 2											
AQ1	0.702	*	*	0.273	*	3.350	0.461	0.563	0.032	*	*
AQ2	0.633	*	*	0.480	*	2.201	0.871	0.629	0.030	*	*
AQ3	0.741	*	*	0.408	*	0.683	0.796	0.430	0.074	*	*
AQ5	2.015	*	*	0.495	*	1.372	0.914	1.177	0.045	*	*

Table 4.6-3 Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	111TCE	112TCE	DCLE11	DCLE12	BCHPD	C6H6	CCl4	CH2CL2	CHCL3	CLC6H5	DBCP
AVERAGE VALUES											
PHASE 3											
AQ1	2.214	*	*	0.053	*	1.132	0.338	19.853	0.069	*	*
AQ2	1.380	*	*	0.044	*	1.096	0.323	16.860	0.047	*	*
AQ3	1.052	*	*	*	*	1.013	0.346	11.812	*	*	*
AQ5	2.331	*	*	0.050	*	1.118	0.337	24.012	0.044	*	*
AQ6	2.863	*	*	0.065	*	1.516	0.485	1.985	0.170	*	*
CMP/BF2	0.858	*	*	*	*	0.797	0.343	9.138	0.363	*	*
CMP/BF3	1.326	*	*	*	*	0.767	0.294	21.641	0.058	*	*
CMP/BF4	1.445	*	*	*	*	0.992	0.520	8.977	0.084	*	*
CMP/BF6	1.080	*	*	0.041	*	0.879	0.334	15.710	0.156	*	*
AQ01	1.782	*	*	0.051	0.074	1.147	0.572	3.996	1.023	0.026	*
AQ36	1.929	*	*	*	*	1.035	0.457	1.112	0.360	*	*
PHASE 4											
AQ1	2.197	*	*	0.054	*	3.081	0.559	5.518	0.169	*	*
AQ2	0.996	*	*	0.061	*	1.378	0.337	3.214	0.037	*	*
AQ3	1.801	*	*	0.073	*	1.548	0.493	3.620	0.180	*	*
AQ4	1.603	*	*	0.047	*	1.761	0.505	4.358	0.093	*	*
AQ5	3.225	*	*	0.080	*	2.563	0.527	4.696	0.093	*	*
AQ6	4.044	*	*	*	*	1.865	0.366	5.873	0.171	*	*
AQ8	3.073	*	*	*	1.081	3.307	0.390	13.225	9.653	*	*
AQ9	2.576	*	*	*	*	2.851	0.392	13.299	0.330	*	*
AQ10	3.066	*	*	0.055	*	1.413	0.388	10.573	0.226	*	*
AQ01	1.514	*	*	0.027	0.195	1.324	0.322	2.424	0.313	0.027	*
AQ02	4.115	*	*	*	*	1.898	0.337	13.281	0.208	*	*
AQ23	2.305	*	*	0.089	*	1.415	0.585	7.578	0.584	*	*
AQ26	2.132	*	*	0.095	*	1.573	0.510	6.401	0.365	*	*
AQ35	1.323	*	*	0.097	*	1.220	0.401	1.372	0.080	*	*
AQ36	2.554	*	*	*	0.150	1.180	1.357	13.189	1.679	*	*

Table 4.6-3 Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	DCPD	DMDS	ETC6H5	MEC6H5	MBK	NNDMEA	DMB12	T12DCE	TCLEE	TRCLE	XYLENE
AVERAGE VALUES											
PHASE 1											
AQ1	*	*	0.713	8.610	0.074	*	0.930	*	0.864	0.110	1.689
AQ2	0.574	*	1.677	11.333	*	*	2.513	*	3.349	0.090	1.890
AQ3	*	*	0.285	3.979	0.078	*	0.438	*	0.699	0.097	0.725
AQ4	*	*	*	11.640	*	*	*	*	*	*	*
AQ5	*	*	0.332	3.853	0.066	*	0.410	*	0.778	0.094	0.880
AQ8	*	*	*	0.704	*	*	*	*	*	*	*
AQ9	*	*	*	0.525	*	*	*	*	*	*	*
AQ01	*	*	0.258	2.481	0.072	*	0.253	*	0.354	0.105	0.813
AQ36	*	*	*	0.656	*	*	*	*	*	0.303	*
CMP/BF1	0.171	0.148	0.521	5.120	0.075	*	0.251	*	0.406	0.079	1.422
CMP/BF2	1.719	0.578	2.394	9.443	0.099	*	0.337	*	0.606	0.497	3.542
CMP/BF3	*	*	0.242	2.810	0.054	*	0.270	*	0.554	*	0.526
CMP/BF4	*	0.144	0.158	2.070	0.045	*	0.258	*	0.170	*	0.597
PHASE 2 - STAGE 2											
AQ1	*	*	0.894	9.311	*	*	1.439	*	0.817	0.091	3.759
AQ2	*	*	0.599	7.488	*	*	0.878	*	1.043	*	2.519
AQ3	*	*	0.283	6.223	*	*	0.379	*	0.407	*	0.902
AQ5	*	*	0.675	10.016	*	*	0.982	*	2.928	*	2.276
PHASE 3											
AQ1	*	*	0.338	4.866	*	*	0.435	*	0.825	0.134	0.981
AQ2	*	*	0.208	5.532	*	*	0.304	*	0.508	0.089	0.692
AQ3	*	*	0.132	1.006	*	*	0.136	*	0.562	*	0.409
AQ5	*	*	0.364	5.306	*	*	0.428	*	1.906	*	0.929
AQ6	*	*	0.233	2.505	0.475	*	0.300	*	0.482	*	0.869
CMP/BF2	*	*	0.193	2.852	*	*	0.249	*	0.360	*	0.715
CMP/BF3	*	*	0.218	2.929	*	*	0.248	*	0.354	*	0.710
CMP/BF4	*	*	0.252	3.901	0.089	*	0.338	*	0.988	0.115	0.970
CMP/BF6	*	*	0.166	2.316	*	*	0.152	*	1.137	0.610	0.538
AQ01	*	*	0.165	2.060	0.079	*	0.214	*	0.286	0.030	0.576
AQ36	*	*	0.165	1.976	0.173	*	0.211	*	0.768	0.123	0.561

Table 4.6-3 Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	DMB12	T12DCE	TCLEE	TRCLE	XYLENE
AVERAGE VALUES											
PHASE 4											
AQ1	*	*	1.382	9.228	0.257	*	1.818	*	1.658	0.141	3.881
AQ2	*	*	0.438	5.469	*	*	0.485	*	1.293	*	1.288
AQ3	*	*	0.627	4.459	0.103	*	0.813	*	0.918	0.078	2.544
AQ4	*	*	0.652	5.969	0.078	*	0.851	*	0.718	0.054	1.804
AQ5	*	*	1.011	8.109	0.173	*	1.344	*	2.389	0.093	2.955
AQ6	*	*	0.222	5.553	0.160	*	0.271	*	0.656	0.138	0.872
AQ8	*	*	0.450	11.254	*	*	0.499	*	0.665	0.199	3.533
AQ9	*	*	0.385	5.659	*	*	0.502	*	0.669	0.140	1.777
AQ10	*	*	0.313	5.321	0.201	*	0.352	*	0.662	0.098	1.009
AQ01	0.053	*	0.417	9.162	0.114	*	0.604	*	1.166	0.055	1.484
AQ02	*	*	0.452	5.651	0.251	*	0.501	*	1.336	0.124	1.331
AQ23	*	*	0.371	7.036	*	*	0.496	*	0.664	0.165	1.105
AQ26	*	*	0.311	5.340	*	*	0.553	*	0.869	0.064	1.246
AQ35	*	*	0.451	3.490	*	*	0.518	*	0.676	*	1.374
AQ36	*	*	0.411	8.394	*	*	0.745	*	0.663	0.336	2.850

Table 4.6-3 Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	111TCE	112TCE	DCLE11	DCLE12	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
MAXIMUM VALUES											
PHASE 1											
AQ1	3.022	*	*	0.148	*	4.646	0.697	5.527	1.546	0.230	*
AQ2	2.450	*	*	*	*	4.282	0.354	3.995	0.365	*	*
AQ3	1.450	*	*	0.175	0.394	3.715	0.496	1.513	0.310	*	*
AQ4	2.964	*	*	0.358	*	13.376	2.277	3.330	2.901	*	*
AQ5	5.264	*	*	*	*	4.392	0.687	7.788	0.503	*	*
AQ8	0.547	*	*	*	*	4.426	0.457	0.753	11.762	*	*
AQ9	1.081	*	*	*	*	1.821	0.614	1.504	0.169	*	*
AQ01	1.703	*	*	0.062	*	1.795	0.658	5.686	4.649	0.333	*
AQ36	0.753	*	*	*	*	0.637	0.626	0.870	0.802	*	*
CMP/BF1	1.610	*	*	*	*	44.293	0.516	2.436	0.506	1.415	0.414
CMP/BF2	1.076	0.062	*	*	12.649	7.370	0.621	22.840	14.520	2.527	17.039
CMP/BF3	1.595	0.271	*	0.054	*	4.635	1.123	0.981	0.625	*	*
CMP/BF4	0.937	*	*	*	*	2.332	0.674	1.083	0.708	*	*
PHASE 2 - STAGE 2											
AQ1	0.702	*	*	0.273	*	3.350	0.461	0.563	0.032	*	*
AQ2	0.633	*	*	0.480	*	2.201	0.871	0.629	0.030	*	*
AQ3	0.741	*	*	0.408	*	0.683	0.796	0.430	0.074	*	*
AQ5	2.015	*	*	0.495	*	1.372	0.914	1.177	0.045	*	*

Table 4.6-3 Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	111TCE	112TCE	DCLE11	DCLE12	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
MAXIMUM VALUES											
PHASE 3											
AQ1	3.238	*	*	0.066	*	1.351	0.409	55.740	0.114	*	*
AQ2	1.682	*	*	0.048	*	1.279	0.430	47.376	0.048	*	*
AQ3	1.095	*	*	*	*	1.251	0.445	34.008	*	*	*
AQ5	3.104	*	*	0.056	*	1.230	0.488	63.102	0.049	*	*
AQ6	2.863	*	*	0.065	*	1.516	0.485	1.985	0.170	*	*
CMP/BF2	1.151	*	*	*	*	1.112	0.403	14.205	0.981	*	*
CMP/BF3	1.907	*	*	*	*	0.932	0.373	38.977	0.096	*	*
CMP/BF4	1.887	*	*	*	*	1.304	1.050	16.664	0.143	*	*
CMP/BF6	1.246	*	*	0.047	*	1.124	0.436	41.716	0.292	*	*
AQ01	3.552	*	*	0.201	*	2.396	1.164	18.476	3.931	0.082	*
AQ36	2.019	*	*	*	*	1.127	0.486	1.234	0.466	*	*
PHASE 4											
AQ1	5.020	*	*	0.118	*	4.751	1.147	19.809	0.478	*	*
AQ2	0.996	*	*	0.061	*	1.378	0.337	3.214	0.037	*	*
AQ3	3.963	*	*	0.155	*	2.900	0.993	13.243	0.444	*	*
AQ4	3.521	*	*	0.090	*	4.640	0.996	13.960	0.294	*	*
AQ5	7.161	*	*	0.178	*	7.548	1.169	13.262	0.214	*	*
AQ6	4.044	*	*	*	*	1.865	0.366	5.873	0.171	*	*
AQ8	3.073	*	*	*	1.081	3.307	0.390	13.225	9.653	*	*
AQ9	2.576	*	*	*	*	2.851	0.392	13.299	0.330	*	*
AQ10	4.610	*	*	0.095	*	1.890	0.390	19.837	0.285	*	*
AQ01	4.571	*	*	0.052	0.541	1.874	0.397	13.114	0.698	0.046	*
AQ02	4.115	*	*	*	*	1.898	0.337	13.281	0.208	*	*
AQ23	3.591	*	*	0.163	*	1.419	0.781	13.169	0.967	*	*
AQ26	4.616	*	*	0.168	*	3.761	0.781	13.243	0.486	*	*
AQ35	1.562	*	*	0.102	*	1.441	0.404	1.399	0.083	*	*
AQ36	2.576	*	*	*	0.267	1.425	1.929	13.299	2.386	*	*

Table 4.6-3 Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	DMB12	T12DCE	TCLEE	TRCLE	XYLENE
MAXIMUM VALUES											
PHASE 1											
AQ1	*	*	2.656	34.438	0.152	*	4.418	*	3.924	0.262	4.854
AQ2	0.574	*	1.677	11.333	*	*	2.513	*	3.349	0.090	1.890
AQ3	*	*	0.801	8.619	0.141	*	1.850	*	1.972	0.310	1.515
AQ4	*	*	*	27.551	*	*	*	*	*	*	*
AQ5	*	*	0.954	8.260	0.243	*	1.563	*	2.929	0.169	3.069
AQ8	*	*	*	1.105	*	*	*	*	*	*	*
AQ9	*	*	*	0.814	*	*	*	*	*	*	*
AQ01	*	*	0.723	6.000	0.120	*	0.647	*	0.762	0.182	2.228
AQ36	*	*	*	1.071	*	*	*	*	*	0.510	*
CMP/BF1	0.430	0.347	2.000	10.366	0.219	*	0.541	*	0.851	0.104	6.031
CMP/BF2	5.628	1.896	13.041	23.525	0.326	*	0.628	*	1.049	2.632	16.240
CMP/BF3	*	*	0.350	4.672	0.065	*	0.435	*	0.906	*	0.857
CMP/BF4	*	0.261	0.238	2.921	0.049	*	0.382	*	0.212	*	0.887
PHASE 2 - STAGE 2											
AQ1	*	*	0.894	9.311	*	*	1.439	*	0.817	0.091	3.759
AQ2	*	*	0.599	7.488	*	*	0.878	*	1.043	*	2.519
AQ3	*	*	0.283	6.223	*	*	0.379	*	0.407	*	0.902
AQ5	*	*	0.675	10.016	*	*	0.982	*	2.928	*	2.276

Table 4.6-3 Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	DMB12	T12DCE	TCLEF	TRCLE	XYLENE
MAXIMUM VALUES											
PHASE 3											
AQ1	*	*	0.772	9.317	*	*	0.992	*	1.041	0.238	2.327
AQ2	*	*	0.309	10.157	*	*	0.397	*	1.257	0.107	0.897
AQ3	*	*	0.202	1.556	*	*	0.274	*	1.354	*	0.630
AQ5	*	*	0.696	7.672	*	*	0.786	*	3.022	*	1.873
AQ6	*	*	0.233	2.505	0.475	*	0.300	*	0.482	*	0.869
CMP/BF2	*	*	0.448	4.756	*	*	0.641	*	0.669	*	1.701
CMP/BF3	*	*	0.366	6.284	*	*	0.495	*	0.619	*	1.315
CMP/BF4	*	*	0.533	7.216	0.229	*	0.788	*	2.221	0.181	2.091
CMP/BF6	*	*	0.299	3.959	*	*	0.331	*	2.406	1.436	1.050
AQ01	*	*	0.389	3.502	0.603	*	0.487	*	0.793	0.111	1.319
AQ36	*	*	0.168	2.043	0.333	*	0.212	*	0.929	0.139	0.573
PHASE 4											
AQ1	*	*	5.294	16.881	1.045	*	5.870	*	4.627	0.295	9.523
AQ2	*	*	0.438	3.469	*	*	0.485	*	1.293	*	1.288
AQ3	*	*	3.086	11.254	0.449	*	3.519	*	2.931	0.195	9.036
AQ4	*	*	2.962	11.479	0.546	*	3.431	*	2.286	0.148	5.205
AQ5	*	*	3.776	16.693	0.694	*	4.934	*	5.894	0.316	8.380
AQ6	*	*	0.222	5.553	0.160	*	0.271	*	0.656	0.138	0.872
AQ8	*	*	0.450	11.254	*	*	0.499	*	0.663	0.199	3.533
AQ9	*	*	0.385	5.659	*	*	0.502	*	0.669	0.140	1.777
AQ10	*	*	0.446	5.627	0.204	*	0.494	*	0.665	0.156	1.312
AQ01	0.119	*	0.467	11.377	0.280	*	0.987	*	1.978	0.144	1.786
AQ02	*	*	0.452	5.651	0.251	*	0.501	*	1.336	0.124	1.331
AQ23	*	*	0.410	11.270	*	*	0.500	*	0.666	0.290	1.327
AQ26	*	*	0.448	11.270	*	*	1.000	*	1.332	0.118	2.637
AQ35	*	*	0.471	4.003	*	*	0.528	*	0.704	*	1.402
AQ36	*	*	0.418	11.129	*	*	0.987	*	0.669	0.488	4.368

Table 4.6-3 Summary of CMP Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

* All values below CRL

Legend:	111TCE	1,1,1-Trichloroethane	DCPD	Dicyclopentadiene
	112TCE	1,1,2-Trichloroethane	DMDS	Dimethyl disulfide
	DCLE11	1,1-Dichloroethane	ETC6H5	Ethylbenzene
	DCLE12	1,2-Dichloroethane	MEC6H5	Toluene
	BCHPD	Bicycloheptadiene	MIBK	Methylisobutylketone
	C6H6	Benzene	NN'DMEA	N-Nitrosodimethylamine
	CCl4	Carbon Tetrachloride	DMB12	Dimethylbenzene
	CH2CL2	Methylene Chloride	T12DCE	Trans-1,2-Dichloroethene
	CHCL3	Chloroform	TCLEE	Tetrachloroethene
	CLC6H5	Chlorobenzene	TRCLE	Trichloroethene
	DBCP	Dibromochloropropane	XYLENE	Xylene

statistically conclusive results from the Basin F monitoring programs adjacent to the remedial operations are provided in Section 4.6.3.2. The CMP data, however, also reflect the dispersal characteristics of potential Basin F contaminants outside the immediate vicinity of Basin F and impacting Arsenal perimeter areas. The decrease in potential contaminant levels with increased distance from Basin F is clearly evident; these results are provided in further detail in Section 4.6.3.3.

4.6.3.2 Basin F Data

Table 4.6-4 shows average and 24-hour maximum VOC concentrations for the Basin F Remedial Monitoring Program and for the IRA-F Monitoring Program for each phase of the remedial and post-remedial activities. All Phase 1 data and Phase 2 data (Stage 1 and Stage 2) were obtained from the Basin F Remedial Monitoring Program and RIFS Odor Program and cover the period from March 22, 1988, to May 5, 1989. The Phase 3 and Phase 4 data were obtained from the IRA-F Monitoring Program and cover the post-remedial period from May 6 to September 30, 1990. Concentrations greater than the CRL were included in the annual and maximum summaries only when estimates of the actual values were available from the lab. Sequential data for the IRA-F program are provided in Appendix O.

Table 4.6-4 provides a detailed summary for each VOC target compound for each remediation phase at the seven Basin F and two RIFS monitoring sites. It can be seen from these data that several VOC compounds measured higher levels in the vicinity of Basin F during the Phase 1 and/or Phase 2 periods, while noticeable decreases for these same compounds were then measured in the Phase 3 and Phase 4 post-remedial periods. Specific VOCs observed at higher levels during the remediation period included methylene chloride, acetone, chloroform, 1,1,1-trichloroethane, carbon tetrachloride, toluene, bicycloheptadiene, dimethyl disulfide, dicyclopentadiene, chlorobenzene, xylene and 1,2-dichloroethane. Several of the higher levels during Phase 1 were the result of isolated maximum values such as for chloroform, chlorobenzene, xylene and 1,2-dichloroethane. Some of the variations in the compound levels may be from regional sources that were measured at higher levels because of specific seasonal and other meteorological influences and not necessarily because they were emitted as a result of Basin F remediation activities. For example, the highest carbon tetrachloride average values were measured during Phase 2, Stage 1 at the Arsenal eastern boundary and the off-site RIFS2 site and may have been a reflection of Commerce City industrial activity. Several VOCs measured may also have resulted from gasoline and diesel fume releases from heavy vehicle activities associated with the remediation, including 1,1,1-trichloroethane, benzene, chloroform and toluene. Also, several of these compounds were observed at high levels at the two RIFS Odor Program sites. These sites

Table 4.6-4 Summary of Basin F/IRA-F/RIFS Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)

	ACET	C6H6	BCHPD	CCL4	111TCE	112TCE	CHCL3	CLC6H5	CS2	DCPD	11DCLE	12DCLE
AVERAGE VALUES												
PHASE 1 (3/22/88 - 12/12/88)												
BF1	9.02	2.45	1.82	0.65	9.44	ND	2.14	0.05	0.02	1.60	ND	0.04
BF2	9.87	3.49	9.96	0.61	8.05	ND	6.95	0.12	0.03	4.53	0.02	0.30
BF2C	5.78	2.94	8.84	0.38	7.12	ND	5.24	0.08	0.02	3.42	ND	ND
BF3	8.36	1.94	0.49	0.52	6.94	ND	0.80	ND	0.02	0.52	ND	0.03
BF4	9.38	2.54	0.55	0.42	10.53	0.05	0.91	0.03	0.02	0.48	ND	ND
BF5	12.50	2.19	0.43	0.53	8.54	ND	0.88	0.02	0.02	0.34	ND	0.03
BF6	11.23	1.86	0.11	0.33	8.82	ND	0.30	ND	ND	0.05	ND	0.02
BF7	14.25	2.15	0.03	0.36	6.24	ND	0.14	ND	0.03	0.03	ND	0.02
RIFS1	*	4.00	0.09	0.47	1.95	ND	0.34	0.03	*	0.35	ND	0.05
PHASE 2 - STAGE 1 (12/13/88 - 2/15/89)												
BF1	13.62	3.97	0.25	1.04	5.50	ND	0.77	0.02	0.03	0.45	ND	ND
BF2	11.82	3.79	0.88	0.92	5.85	ND	1.89	0.03	0.03	0.32	ND	0.06
BF2C	13.33	3.85	0.12	1.11	7.93	ND	0.73	ND	0.04	0.08	ND	ND
BF3	9.42	3.32	0.09	0.88	5.03	ND	0.48	ND	ND	0.18	ND	0.02
BF4	13.55	3.78	0.13	0.75	5.22	ND	0.39	ND	0.05	0.21	ND	0.03
BF5	7.93	2.45	0.47	0.97	4.18	ND	0.33	ND	0.06	0.06	ND	0.02
BF6	8.37	3.24	0.06	1.23	4.73	ND	0.35	ND	0.05	ND	ND	0.03
BF7	8.61	3.51	0.03	1.20	5.26	ND	0.35	ND	0.31	0.04	ND	0.02
RIFS1	*	5.89	ND	1.35	2.77	ND	0.31	0.04	*	ND	ND	0.24
RIFS1D	*	7.32	ND	1.74	3.41	ND	1.44	0.03	*	ND	ND	0.16
RIFS2	*	4.95	0.03	1.99	2.49	ND	1.08	0.03	*	ND	ND	0.36
PHASE 2 - STAGE 2 (2/16/89 - 5/5/89)												
BF1	7.78	2.00	0.06	0.78	3.50	ND	0.30	0.03	0.02	0.13	ND	0.03
BF2	6.90	1.65	0.03	0.70	2.57	ND	0.37	0.02	0.02	0.04	ND	0.02
BF2C	20.79	1.01	0.06	0.58	3.19	0.46	0.31	ND	ND	ND	ND	ND
BF3	6.71	1.71	0.03	0.68	2.54	ND	0.18	0.02	0.02	0.03	ND	0.03
BF4	6.36	2.15	0.04	0.67	2.42	ND	0.17	ND	0.02	0.03	ND	0.02
BF5	3.71	1.19	0.02	0.51	1.89	0.19	0.15	0.03	ND	ND	ND	0.02
BF6	3.95	1.41	ND	0.70	2.17	ND	0.18	0.03	ND	ND	ND	ND
BF7	6.49	1.70	0.02	0.76	3.40	ND	0.13	0.03	ND	ND	ND	0.02
RIFS1	*	2.10	ND	0.63	1.64	ND	0.11	0.03	*	ND	ND	0.04
RIFS1D	*	2.28	ND	0.53	1.22	ND	0.11	0.04	*	ND	ND	0.06
RIFS2	*	2.37	ND	0.89	1.30	ND	0.14	ND	*	ND	ND	0.08

Table 4.6-4 Summary of Basin F/IRA-F/RIFS Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)
(continued)

	ACET	C6H6	BCHPD	CCL4	111TCE	112TCE	CHCL3	CLC6H5	CS2	DCPD	11DCLE	12DCLE
AVERAGE VALUES												
PHASE 3 (5/6/89 - 9/30/89)												
FC1	*	1.15	ND	0.35	1.09	ND	0.15	0.02	*	ND	ND	0.02
FC2	*	1.00	ND	0.40	1.01	ND	0.27	0.02	*	ND	ND	0.03
FC2D	*	1.18	ND	0.42	1.11	ND	0.30	0.02	*	ND	ND	0.03
BF3/FC3	*	1.07	ND	0.42	1.09	ND	0.11	0.02	*	ND	ND	0.03
BF4/FC4	*	1.19	ND	0.40	1.16	ND	0.11	0.02	*	ND	ND	0.03
BF5	*	1.06	ND	0.45	0.94	ND	0.10	0.03	*	ND	ND	0.03
FC5	*	0.90	ND	0.37	0.95	ND	0.18	0.02	*	ND	ND	0.02
BF7	*	1.15	ND	0.42	1.25	ND	0.09	0.03	*	ND	ND	0.02
RIFS1	*	1.28	ND	0.39	1.15	ND	0.12	0.03	*	ND	ND	0.03
PHASE 4 (10/1/89 - 9/30/90)												
FC1	*	1.36	ND	0.56	1.40	ND	0.30	0.02	*	ND	ND	0.06
FC2	*	1.33	0.04	0.58	1.41	ND	0.67	0.02	*	ND	ND	0.07
FC2D	*	1.22	0.05	0.49	1.40	ND	0.69	0.02	*	ND	ND	0.06
FC3	*	1.43	0.02	0.60	1.46	0.02	0.20	0.02	*	ND	0.01	0.07
FC4	*	1.38	ND	0.60	1.52	ND	0.18	0.02	*	ND	ND	0.06
FC5	*	1.30	0.02	0.57	1.36	ND	0.36	0.02	*	ND	ND	0.06

Legend:	ACET	Acetone	CHCL3	Chloroform
	C6H6	Benzene	CLC6H5	Chlorobenzene
	BCHPD	Bicycloheptadiene	CS2	Carbon Disulfide
	CCL4	Carbon Tetrachloride	DCPD	Dicyclopentadiene
	111TCE	1,1,1-Trichloroethane	11DCLE	1,1-Dichloroethane
	112TCE	1,1,2-Trichloroethane	12DCLE	1,2-Dichloroethane

* Not a target analyte for this site during this phase.

Table 4.6-4 Summary of Basin F/IRA-F/RIFS Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)
(continued)

	DMDS	ETC6H5	HCBD	MEK	CH2CL2	MIBK	T12DCE	TCLEE	MEC6H5	TRCLE	XYLEN
AVERAGE VALUES (continued)											
PHASE 1 (3/22/88 - 12/12/88)											
BF1	7.86	1.09	*	1.17	10.48	ND	ND	2.12	9.34	0.26	5.61
BF2	5.34	1.58	*	0.79	7.57	ND	ND	5.07	20.95	0.12	8.57
BF2C	6.69	1.56	*	0.89	10.47	ND	ND	3.41	23.55	0.14	7.72
BF3	0.50	0.81	*	0.57	7.17	ND	ND	1.13	8.27	0.21	4.23
BF4	0.91	0.92	*	0.68	6.36	ND	ND	1.13	8.51	0.29	5.02
BF5	0.92	0.77	*	1.29	7.77	ND	ND	1.21	5.47	0.24	3.94
BF6	0.04	0.78	*	0.79	15.89	ND	ND	1.02	7.96	0.18	4.36
BF7	0.02	0.89	*	0.79	4.99	ND	ND	1.07	5.60	0.17	4.57
RIFS1	0.03	1.72	*	*	4.19	0.10	ND	1.56	8.00	0.12	5.44
PHASE 2 - STAGE 1 (12/13/88 - 2/15/89)											
BF1	ND	1.59	ND	3.31	4.01	ND	ND	1.55	5.24	0.17	6.75
BF2	0.02	1.49	ND	3.25	2.52	ND	ND	1.57	5.05	0.11	6.35
BF2C	ND	1.28	ND	3.72	4.23	ND	ND	1.33	5.29	0.11	5.87
BF3	ND	1.45	ND	3.64	3.52	ND	ND	1.37	4.81	0.15	6.40
BF4	ND	1.94	ND	3.83	3.64	ND	ND	1.59	5.02	0.17	8.17
BF5	ND	0.85	ND	2.13	2.12	ND	ND	0.94	3.30	0.09	3.72
BF6	ND	1.02	ND	3.65	1.48	ND	ND	1.14	3.78	0.14	3.84
BF7	ND	1.19	ND	3.61	3.07	ND	0.02	1.20	4.05	0.17	4.45
RIFS1	ND	2.00	*	*	4.42	ND	ND	1.86	8.21	0.17	7.49
RIFS1D	ND	2.36	*	*	5.39	ND	ND	2.06	10.83	0.16	9.45
RIFS2	ND	1.61	*	*	4.46	ND	ND	1.35	7.81	0.11	6.09
PHASE 2 - STAGE 2 (2/16/89 - 5/5/89)											
BF1	0.02	1.07	ND	3.71	4.14	ND	ND	5.29	3.65	6.98	4.88
BF2	ND	0.52	ND	3.09	6.11	ND	ND	0.78	2.84	0.24	2.68
BF2C	ND	0.46	ND	2.57	19.01	ND	ND	0.66	2.82	0.14	2.64
BF3	ND	0.58	ND	2.01	23.81	ND	ND	0.78	3.19	0.08	2.98
BF4	ND	0.79	ND	2.96	3.23	ND	ND	0.94	3.62	0.16	3.98
BF5	ND	0.41	ND	2.47	1.29	ND	ND	0.61	2.45	0.07	2.22
BF6	ND	0.51	ND	2.97	2.81	ND	ND	0.65	2.82	0.05	2.87
BF7	ND	0.61	ND	3.53	2.94	ND	ND	0.85	3.52	0.04	3.12
RIFS1	ND	0.72	*	*	2.38	ND	ND	0.93	6.10	0.06	3.30
RIFS1D	ND	0.67	*	*	1.23	ND	ND	0.82	6.66	0.04	3.75
RIFS2	ND	0.69	*	*	1.33	ND	ND	0.77	6.03	0.04	3.14

Table 4.6-4 Summary of Basin F/IRA-F/RIFS Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)
(continued)

	DMDs	ETC6H5	HCBD	MEK	CH2CL2	MIBK	T12DCE	TCLEE	MEC6H5	TRCLE	XYLEN
AVERAGE VALUES (continued)											
PHASE 3 (5/6/89 - 9/30/89)											
FC1	ND	0.45	*	*	0.74	0.03	ND	0.71	1.78	0.30	1.52
FC2	ND	0.60	*	*	0.55	0.02	ND	0.61	1.80	0.04	1.38
FC2D	ND	0.38	*	*	0.33	0.02	ND	0.54	2.10	0.03	1.33
BF3/FC3	ND	0.42	*	*	0.73	0.03	ND	0.55	1.65	0.04	1.38
BF4/FC4	ND	0.47	*	*	0.92	0.04	ND	0.70	2.20	0.04	1.55
BF5	ND	0.36	*	*	0.31	ND	ND	0.56	1.67	0.05	1.30
FC5	ND	0.41	*	*	1.17	0.04	ND	0.55	1.85	0.44	1.31
BF7	ND	0.36	*	*	0.45	0.02	ND	0.69	1.98	0.03	1.29
RIFS1	ND	0.48	*	*	0.48	ND	ND	0.70	2.26	0.04	1.69
PHASE 4 (10/1/89 - 9/30/90)											
FC1	ND	0.57	*	*	0.53	0.09	ND	0.77	3.92	0.07	1.65
FC2	ND	0.53	*	*	0.51	0.08	ND	0.92	3.71	0.05	1.66
FC2D	ND	0.55	*	*	0.51	0.10	ND	0.80	3.56	0.05	1.44
FC3	ND	0.60	*	*	0.50	0.10	0.02	0.89	3.62	0.06	1.61
FC4	ND	0.65	*	*	0.56	0.10	ND	0.86	3.42	0.06	1.65
FC5	ND	0.55	*	*	0.47	0.09	ND	0.79	3.53	0.10	1.63

Legend:	DMDs	Dimethyl Disulfide	T12DCE	Trans-1,2-Dichloroethene
	ETC6H5	Ethylbenzene	TCLEE	Tetrachloroethene
	HCBD	Hexachlorobutadiene	MEC6H5	Toluene
	MEK	Methyl Ethyl Ketone	TRCLE	Trichloroethane
	CH2CL2	Methylene Chloride	XYLEN	Xylenes
	MIBK	Methylisobutylketone		

* Not a target analyte for this site during this phase.

Table 4.6-4 Summary of Basin F/IRA-F/RIFS Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)
(continued)

	ACET	C6H6	BCHPD	CCL4	111TCE	112TCE	CHCL3	CLC6H5	CS2	DCPD	11DCLE	12DCLE
24-HOUR MAXIMUM VALUES												
PHASE 1 (3/22/88 - 12/12/88)												
BF1	47.73	6.89	17.98	3.89	72.54	ND	18.51	0.45	0.08	4.58	ND	0.23
BF2	55.53	10.83	39.46	6.68	53.40	ND	37.15	0.80	0.24	29.12	0.08	1.89
BF2C	28.58	9.22	26.19	1.60	28.58	ND	31.14	0.52	0.05	8.30	ND	ND
BF3	81.55	5.20	2.69	4.00	62.88	ND	3.11	ND	0.05	6.04	ND	0.24
BF4	112.12	6.52	12.25	5.61	67.00	1.12	18.03	0.39	0.03	3.74	ND	ND
BF5	121.38	6.82	2.64	1.19	40.48	ND	5.65	0.05	0.04	2.15	ND	0.15
BF6	41.93	5.74	0.50	1.17	71.11	ND	1.70	ND	ND	0.41	ND	0.09
BF7	151.22	6.47	0.13	1.41	22.06	ND	0.67	ND	0.14	0.14	ND	0.04
RIFS1	*	9.59	0.49	0.95	4.78	ND	1.33	0.12	*	3.77	ND	0.25
PHASE 2 - STAGE 1 (12/13/88 - 2/15/89)												
BF1	56.24	8.87	1.77	1.93	9.45	ND	3.24	0.06	0.09	3.36	ND	ND
BF2	42.24	7.78	6.66	2.21	17.47	ND	16.41	0.10	0.12	2.48	ND	0.59
BF2C	44.49	6.07	0.46	1.75	28.90	ND	1.57	ND	0.22	0.18	ND	ND
BF3	30.04	6.83	0.85	2.52	11.48	ND	1.19	ND	ND	1.27	ND	0.11
BF4	54.75	8.97	1.51	1.30	15.74	ND	0.92	ND	0.29	1.37	ND	0.24
BF5	22.34	4.71	7.27	1.59	8.55	ND	0.75	ND	0.71	0.60	ND	0.12
BF6	24.50	8.57	0.37	2.25	8.04	ND	0.86	ND	0.31	ND	ND	0.10
BF7	14.23	9.64	0.08	2.39	9.75	ND	0.90	0.11	1.99	0.17	ND	0.08
RIFS1	*	11.80	ND	8.59	6.38	ND	1.06	0.32	*	ND	ND	3.41
RIFS1D	*	14.20	ND	4.46	5.38	ND	10.00	0.06	*	ND	ND	1.09
RIFS2	*	10.90	0.74	9.76	4.65	ND	10.00	0.10	*	ND	ND	3.80
PHASE 2 - STAGE 2 (2/16/89 - 5/5/89)												
BF1	24.39	4.08	0.91	1.13	12.51	ND	1.11	0.08	0.12	2.54	ND	0.10
BF2	22.60	3.23	0.23	1.16	5.29	ND	0.71	0.08	0.09	0.35	ND	0.08
BF2C	43.47	2.55	0.41	1.38	8.00	4.00	0.72	ND	ND	ND	ND	ND
BF3	22.49	4.14	0.12	1.09	5.16	ND	0.60	0.07	0.09	0.17	ND	0.10
BF4	17.73	4.34	0.29	0.97	6.66	ND	0.48	ND	0.09	0.12	ND	0.06
BF5	7.11	2.44	0.04	0.76	3.34	1.90	0.36	0.09	ND	ND	ND	0.07
BF6	6.29	2.60	ND	0.87	4.22	ND	0.44	0.09	ND	ND	ND	ND
BF7	16.22	3.10	0.04	0.99	8.54	ND	0.26	0.09	ND	ND	ND	0.06
RIFS1	*	6.72	ND	2.83	8.75	ND	0.30	0.17	*	ND	ND	0.21
RIFS1D	*	3.35	ND	0.80	1.66	ND	0.27	0.12	*	ND	ND	0.14
RIFS2	*	5.73	ND	1.24	2.64	ND	0.27	ND	*	ND	ND	0.34

Table 4.6-4 Summary of Basin F/IRA-F/RIFS Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)
(continued)

	ACET	C6H6	BCHPD	CCL4	111TCE	112TCE	CHCL3	CLC6H5	CS2	DCPD	11DCLE	12DCLE
24-HOUR MAXIMUM VALUES												
PHASE 3 (5/6/89 - 9/30/89)												
FC1	*	2.43	ND	0.61	1.79	ND	0.33	0.07	*	ND	ND	0.04
FC2	*	2.72	ND	0.79	1.79	ND	0.69	0.07	*	ND	ND	0.08
FC2D	*	2.55	ND	0.69	1.77	ND	0.76	0.11	*	ND	ND	0.10
BF3/FC3	*	2.78	ND	0.97	1.80	ND	0.30	0.05	*	ND	ND	0.10
BF4/FC4	*	3.00	ND	0.81	2.14	ND	0.33	0.05	*	ND	ND	0.09
BF5	*	2.04	ND	0.77	1.29	ND	0.17	0.08	*	ND	ND	0.09
FC5	*	1.45	ND	0.94	1.41	ND	0.34	0.05	*	ND	ND	0.09
BF7	*	2.10	ND	0.73	2.00	ND	0.16	0.07	*	ND	ND	0.04
RIFS1	*	2.57	ND	0.55	2.14	ND	0.30	0.08	*	ND	ND	0.10
PHASE 4 (10/1/89 - 9/30/90)												
FC1	*	3.53	ND	1.43	3.89	ND	1.32	0.05	*	ND	ND	0.20
FC2	*	3.17	0.22	1.31	4.17	ND	2.23	0.05	*	ND	ND	0.25
FC2D	*	3.16	0.21	1.13	4.33	ND	2.21	0.04	*	ND	ND	0.24
FC3	*	3.33	0.07	1.52	4.34	0.06	0.57	0.07	*	ND	0.05	0.22
FC4	*	2.98	ND	1.64	4.60	ND	0.54	0.04	*	ND	ND	0.24
FC5	*	3.50	0.05	1.43	3.78	ND	1.18	0.04	*	ND	ND	0.23

Legend:	ACET	Acetone	CHCL3	Chloroform
	C6H6	Benzene	CLC6H5	Chlorobenzene
	BCHPD	Bicycloheptadiene	CS2	Carbon Disulfide
	CCL4	Carbon Tetrachloride	DCPD	Dicyclopentadiene
	111TCE	1,1,1-Trichloroethane	11DCLE	1,1-Dichloroethane
	112TCE	1,1,2-Trichloroethane	12DCLE	1,2-Dichloroethane

* Not a target analyte for this site during this phase.

Table 4.6-4 Summary of Basin F/IRA-F/RIFS Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)
(continued)

	DMDS	ETC6H5	HCBD	MEK	CH2CL2	MIBK	T12DCE	TCLEE	MEC6H5	TRCLE	XYLEN
24-HOUR MAXIMUM VALUES (continued)											
PHASE 1 (3/22/88 - 12/12/88)											
BF1	36.72	4.95	*	8.48	54.80	ND	ND	16.02	35.55	1.47	25.94
BF2	24.06	8.91	*	8.14	55.34	ND	ND	23.17	90.10	0.78	49.91
BF2C	23.69	4.95	*	4.60	72.36	ND	ND	9.14	158.04	1.06	17.20
BF3	4.97	3.98	*	5.27	57.64	ND	ND	2.30	49.41	1.00	10.51
BF4	8.07	2.39	*	5.22	58.14	ND	ND	3.40	49.91	1.81	10.39
BF5	3.95	2.48	*	6.45	50.81	ND	ND	3.32	14.49	1.00	10.52
BF6	0.28	1.79	*	5.74	179.09	ND	ND	2.61	51.49	0.62	12.90
BF7	0.10	2.38	*	4.32	30.26	ND	ND	2.66	19.61	0.90	11.56
RIFS1	0.11	3.00	*	*	13.70	0.51	ND	2.80	16.50	0.26	9.22
PHASE 2 - STAGE 1 (12/13/88 - 2/15/89)											
BF1	ND	4.38	ND	14.78	23.52	ND	ND	3.19	13.32	0.57	17.26
BF2	0.08	4.20	ND	14.20	15.73	ND	ND	4.48	11.43	0.34	15.77
BF2C	ND	2.25	ND	9.56	19.59	ND	ND	3.49	8.55	0.22	11.22
BF3	ND	3.75	ND	13.24	23.71	ND	ND	2.83	11.14	0.34	15.57
BF4	ND	8.97	ND	13.22	19.77	ND	ND	5.52	19.52	0.65	28.28
BF5	ND	1.99	ND	10.54	6.51	ND	ND	2.58	8.42	0.17	10.39
BF6	ND	2.50	ND	10.11	2.74	ND	ND	2.33	6.95	0.47	7.68
BF7	ND	2.93	ND	8.45	7.56	ND	0.05	2.57	7.80	0.44	9.29
RIFS1	ND	6.16	*	*	32.50	ND	ND	3.44	23.90	0.61	15.72
RIFS1D	ND	5.69	*	*	22.90	ND	ND	3.44	30.80	0.32	22.43
RIFS2	ND	5.32	*	*	17.00	ND	ND	2.99	29.60	0.31	19.58
PHASE 2 - STAGE 2 (2/16/89 - 5/5/89)											
BF1	0.05	3.62	ND	8.60	28.85	ND	ND	24.02	6.93	40.43	13.54
BF2	ND	1.18	ND	7.64	72.80	ND	ND	2.14	6.22	2.86	6.76
BF2C	ND	1.50	ND	10.25	59.83	ND	ND	1.98	8.57	0.47	8.50
BF3	ND	1.28	ND	7.17	433.69	ND	ND	2.10	7.49	0.21	7.10
BF4	ND	1.72	ND	4.83	14.06	ND	ND	2.04	8.38	0.55	8.92
BF5	ND	1.11	ND	5.54	5.18	ND	ND	1.51	5.67	0.15	6.31
BF6	ND	0.94	ND	7.16	5.74	ND	ND	1.44	5.22	0.11	5.72
BF7	ND	1.11	ND	8.85	6.30	ND	ND	2.27	6.77	0.07	6.25
RIFS1	ND	2.28	*	*	20.50	ND	ND	3.82	21.00	0.21	7.39
RIFS1D	ND	1.07	*	*	2.75	ND	ND	1.67	10.40	0.10	7.01
RIFS2	ND	2.06	*	*	4.91	ND	ND	2.59	15.50	0.07	8.51

Table 4.6-4 Summary of Basin F/IRA-F/RIFS Volatile Organic Compounds (VOC) Concentrations for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)
(continued)

	DMDS	ETC6H5	HCB	MEK	CH2CL2	MBK	T12DCE	TCLEE	MEC6H5	TRCLE	XYLEN
24-HOUR MAXIMUM VALUES (continued)											
PHASE 3 (5/6/89 - 9/30/89)											
FC1	ND	1.04	*	*	3.43	0.14	ND	1.69	3.24	1.52	3.06
FC2	ND	3.99	*	*	3.26	0.18	ND	1.35	2.97	0.12	3.31
FC2D	ND	1.02	*	*	0.65	0.09	ND	1.33	4.40	0.15	3.20
BF3/FC3	ND	1.19	*	*	4.24	0.20	ND	1.63	2.87	0.09	3.57
BF4/FC4	ND	1.25	*	*	4.06	0.21	ND	2.50	5.00	0.11	3.48
BF5	ND	0.75	*	*	0.44	ND	ND	1.16	3.25	0.19	2.61
FC5	ND	1.05	*	*	6.77	0.15	ND	1.44	3.62	0.93	2.51
BF7	ND	0.61	*	*	0.74	0.09	ND	1.60	2.93	0.07	1.97
RIFS1	ND	0.87	*	*	0.92	ND	ND	1.40	3.54	0.10	3.19
PHASE 4 (10/1/89 - 9/30/90)											
FC1	ND	2.27	*	*	2.53	0.63	ND	2.38	10.60	0.45	7.07
FC2	ND	2.67	*	*	1.98	0.88	ND	6.34	10.80	0.23	6.97
FC2D	ND	2.62	*	*	1.57	1.13	ND	2.59	10.70	0.26	7.04
FC3	ND	2.84	*	*	1.60	0.84	0.06	5.98	10.90	0.30	7.07
FC4	ND	3.01	*	*	2.03	1.13	ND	3.51	9.93	0.30	6.62
FC5	ND	2.24	*	*	1.45	0.75	ND	2.91	10.60	0.50	7.09

Legend:	DMDS	Dimethyl Disulfide	T12DCE	Trans-1,2-Dichloroethene
	ETC6H5	Ethylbenzene	TCLEE	Tetrachloroethene
	HCB	Hexachlorobutadiene	MEC6H5	Toluene
	MEK	Methyl Ethyl Ketone	TRCLE	Trichloroethane
	CH2CL2	Methylene Chloride	XYLEN	Xylenes
	MIBK	Methylisobutylketone		

* Not a target analyte for this site during this phase.

were adjacent to moderate to heavy Commerce City traffic activities, including railroad freight car movements; higher VOC levels may well have resulted from these urban sources. Nevertheless, a portion of these VOCs can be assumed to have resulted from the remediation process.

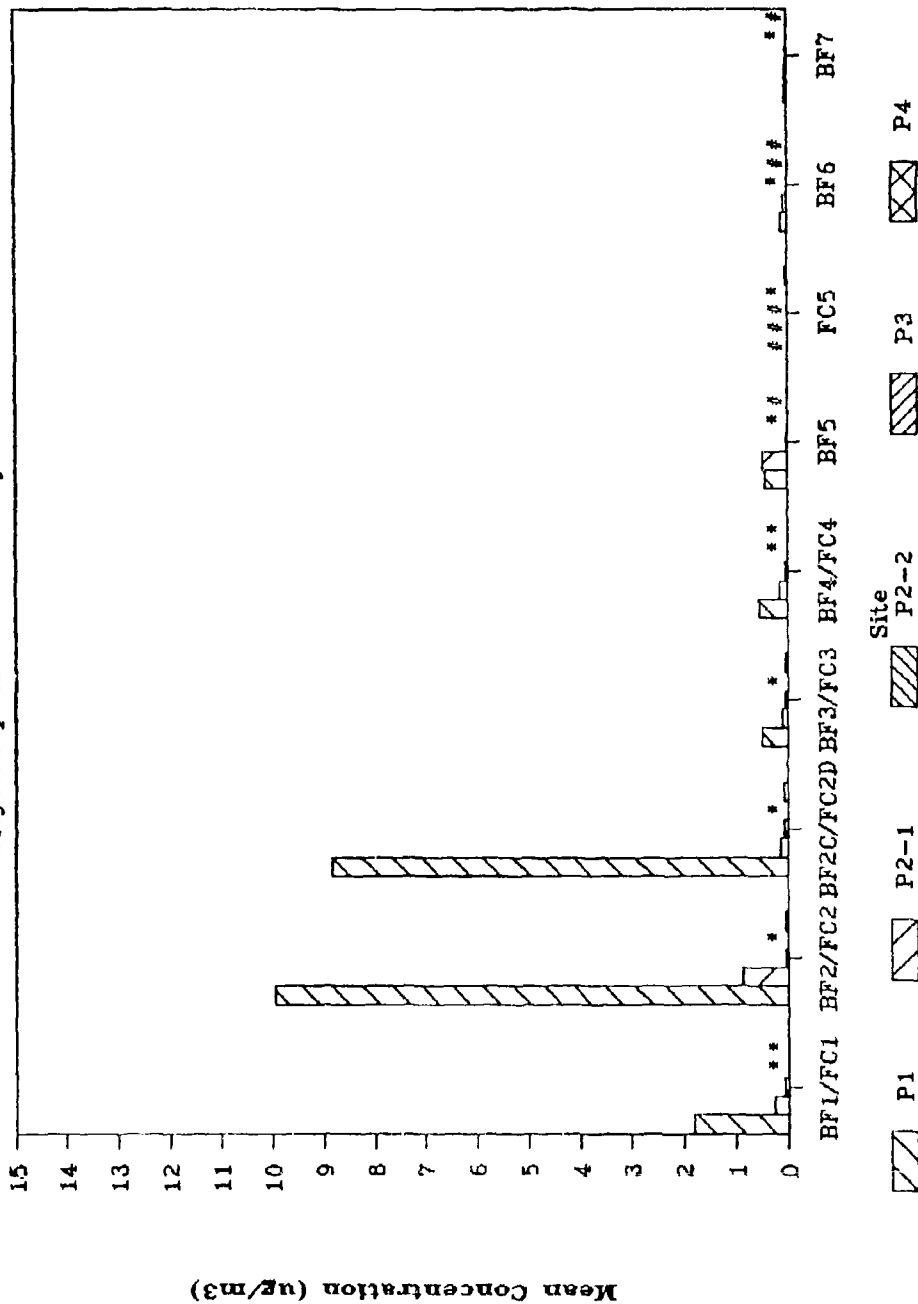
Figures 4.6-7 through 4.6-11 show bar graph depictions of average concentrations of bicycloheptadiene, chloroform, dicyclopentadiene, dimethyl disulfide and toluene measured during each phase of the remediation activities and after the completion of the cleanup program. A significant decrease of these compounds was observed at the termination of the remediation program. Also noted from these data is the decrease in concentration levels (even during Phase 1) with distance from the Basin F source. This suggests that Basin F was the principal emitter of these potential contaminants, and that the impacts were local and decreased beyond the immediate vicinity of the remediation activities. This was confirmed by CMP monitoring results at RMA's more distant monitoring sites and at the boundaries, and will be discussed further in the next section.

As in the case of metals, another approach to assessing remedial progress for VOCs is to consider Basin F impacts that were observed on individual days during the remedial and post-remedial periods. All Basin F monitoring during the Phase 1 and Phase 2 periods was conducted for worst-case 24-hour periods based on dispersion model analysis and remedial activity. An example of the dispersion of VOCs resulting from Basin F Phase 1 remedial activities is shown in Figure 4.6-12. This figure shows VOC concentrations for August 12, 1988, with X/Q dispersion values overlaying the monitoring data for the seven Basin F monitoring sites. Again, this type of analysis identifies, to the fullest extent, the potential dispersion of VOCs and other contaminants resulting from remedial actions at Basin F. During this sample period, the winds were variable in direction and flowed at moderate speeds. The maximum temperature was 88°F. The dispersion pattern shows a broad distribution of 24-hour Basin F impacts of dimethyl disulfide, bicycloheptadiene, and ethylbenzene to the northeast and a secondary distribution to the west through west-northwest. The VOC concentrations at upwind site BF7 were nondetectable. At the perimeter sites around Basin F, the levels were highest at site BF1 immediately downwind of the basin, and at BF2 near the site of the most intense remedial activity.

At the downwind off-site BF5, levels dropped off considerably. These data support the conclusion that Basin F was a source of the reported contaminants.

Figure 4.6-13 shows the X/Q dispersion pattern and the results for a Phase 4 (post-remedial) sample period, July 27-28, 1990, with similar dispersion characteristics as August 12, 1988. Winds on this sample day were moderate and variable, but predominantly from the south. The maximum sample

Bicycloheptadiene Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 4.6-7

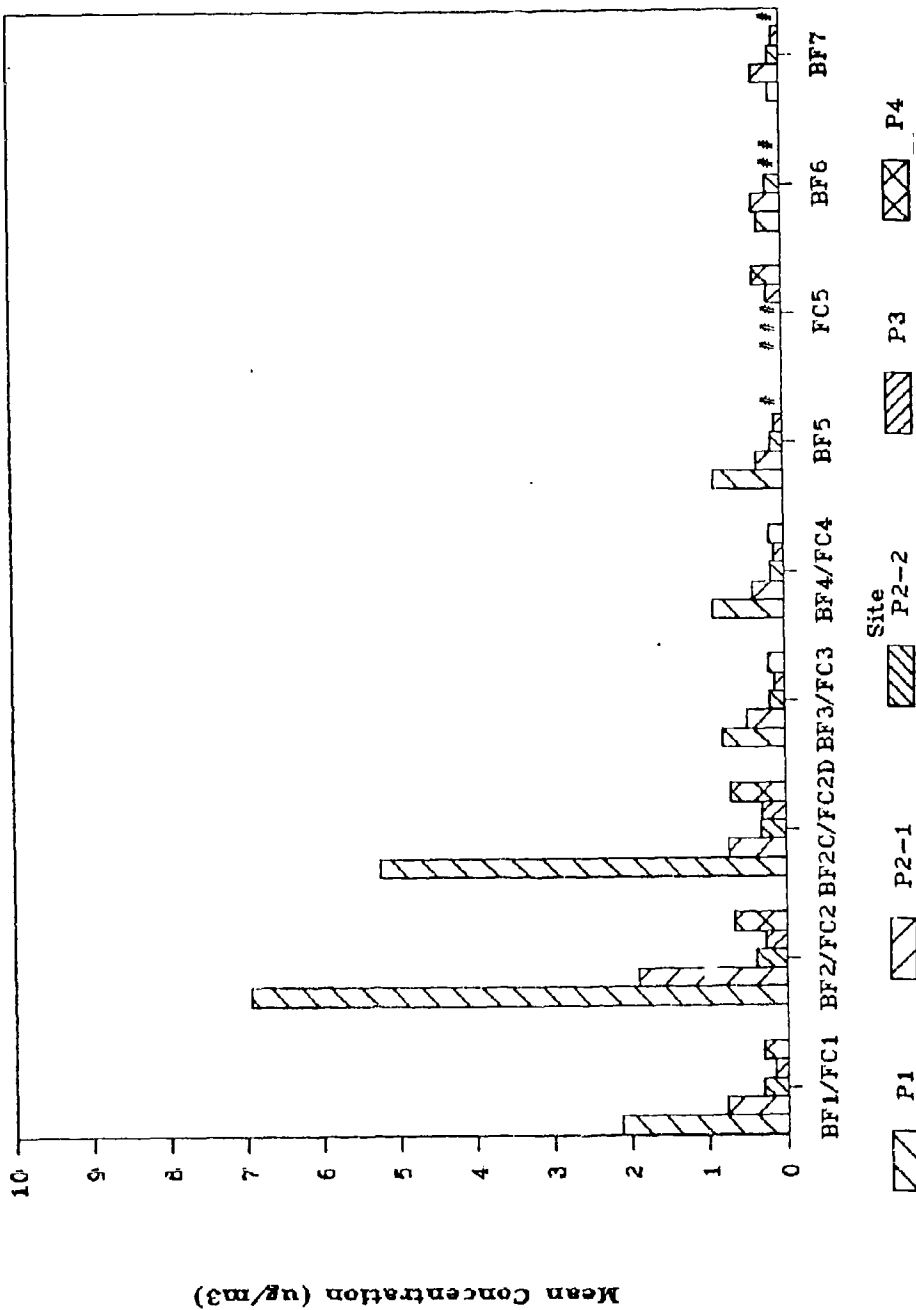
Bicycloheptadiene Results by Phase

CMP AR FY90

* No Samples Taken During this Phase

* Not Detected During this Phase

Chloroform Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 4.6-8

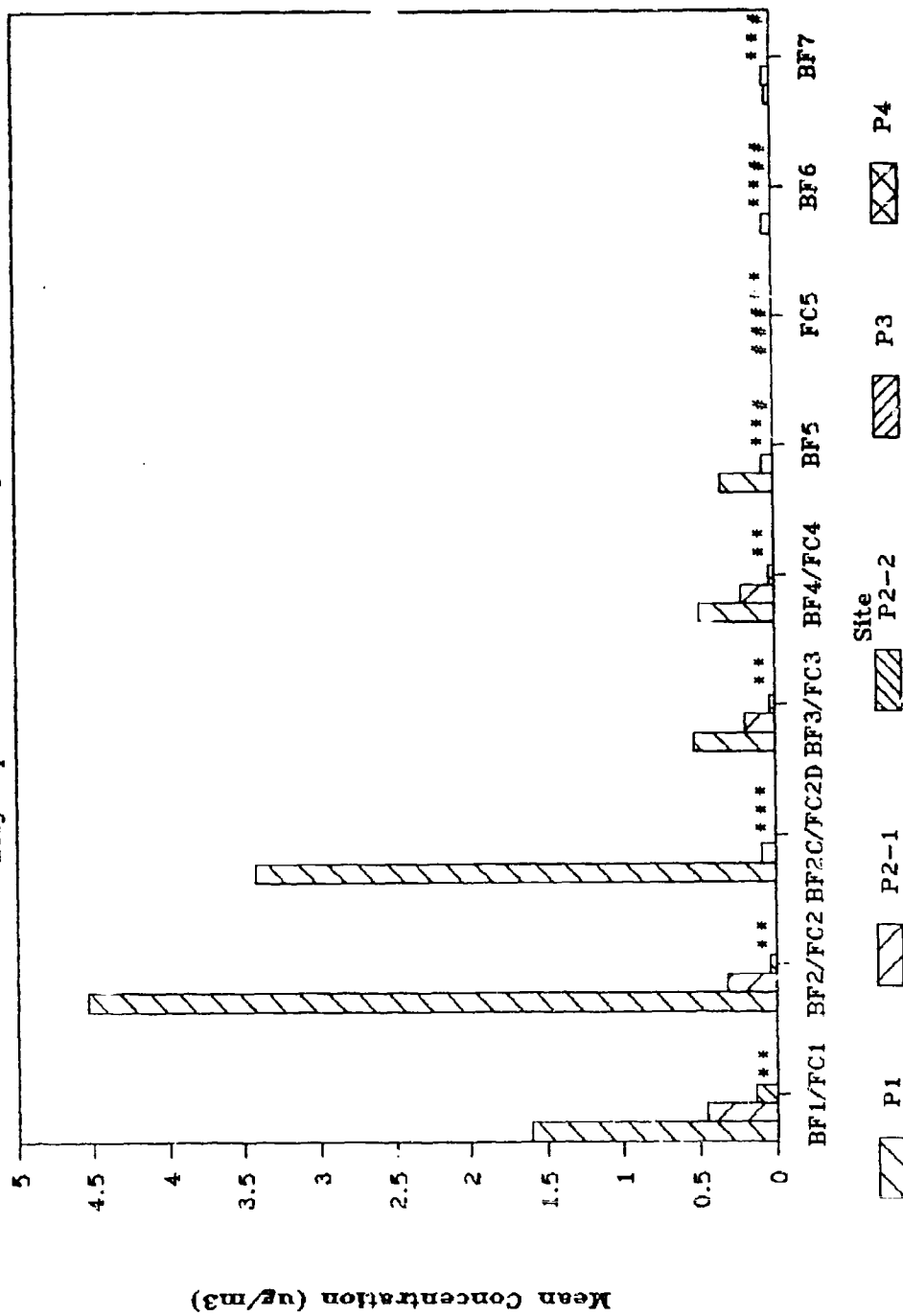
Chloroform Results by Phase

CMP AR FY90

* No Samples Taken During this Phase

* Not Detected During this Phase

Dicyclopentadiene Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

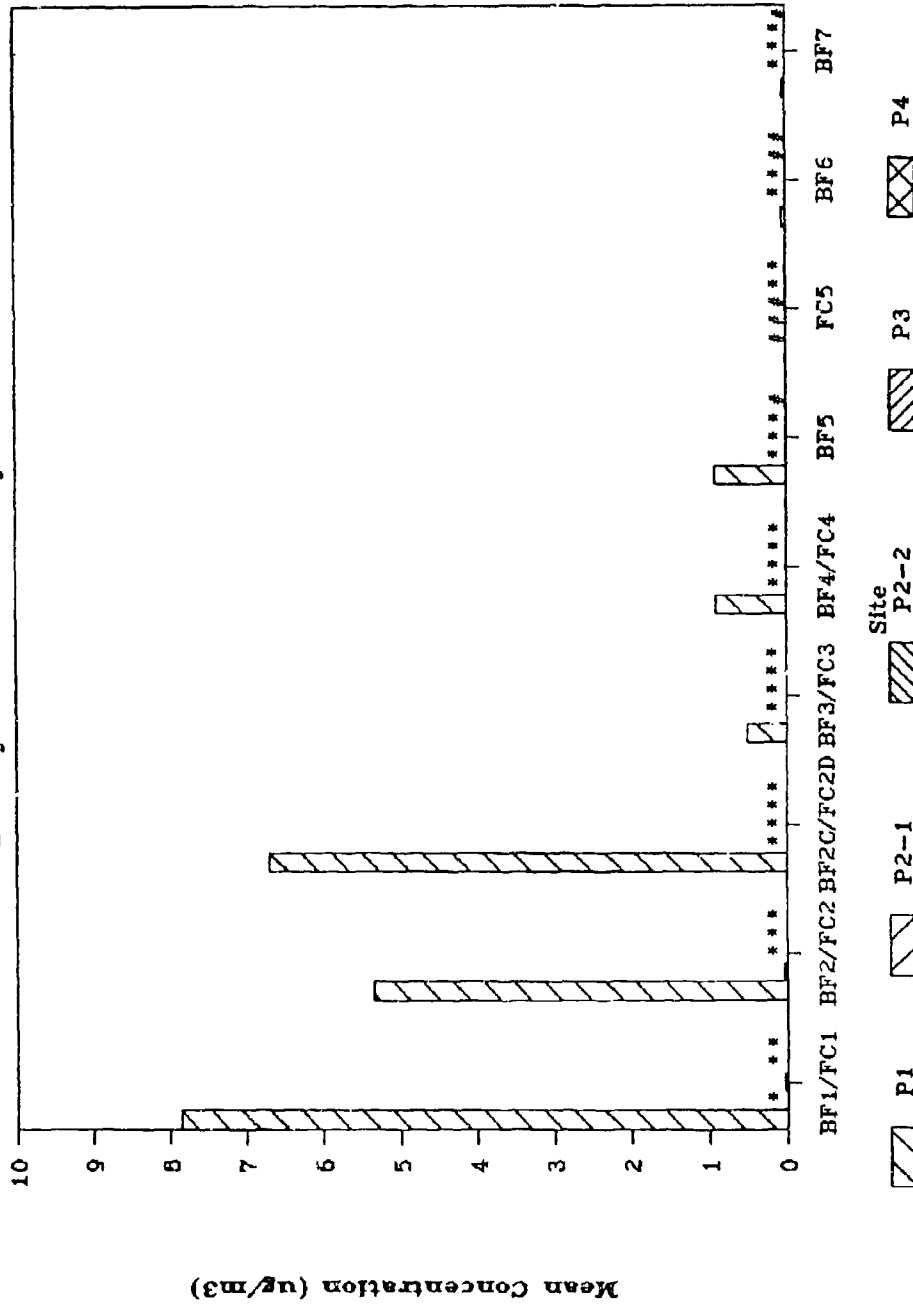
Figure 4.6-9

Dicyclopentadiene Results by Phase

CMP AR FY90

* No Samples Taken During this Phase
* Not Detected During this Phase

Dimethyldisulfide Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

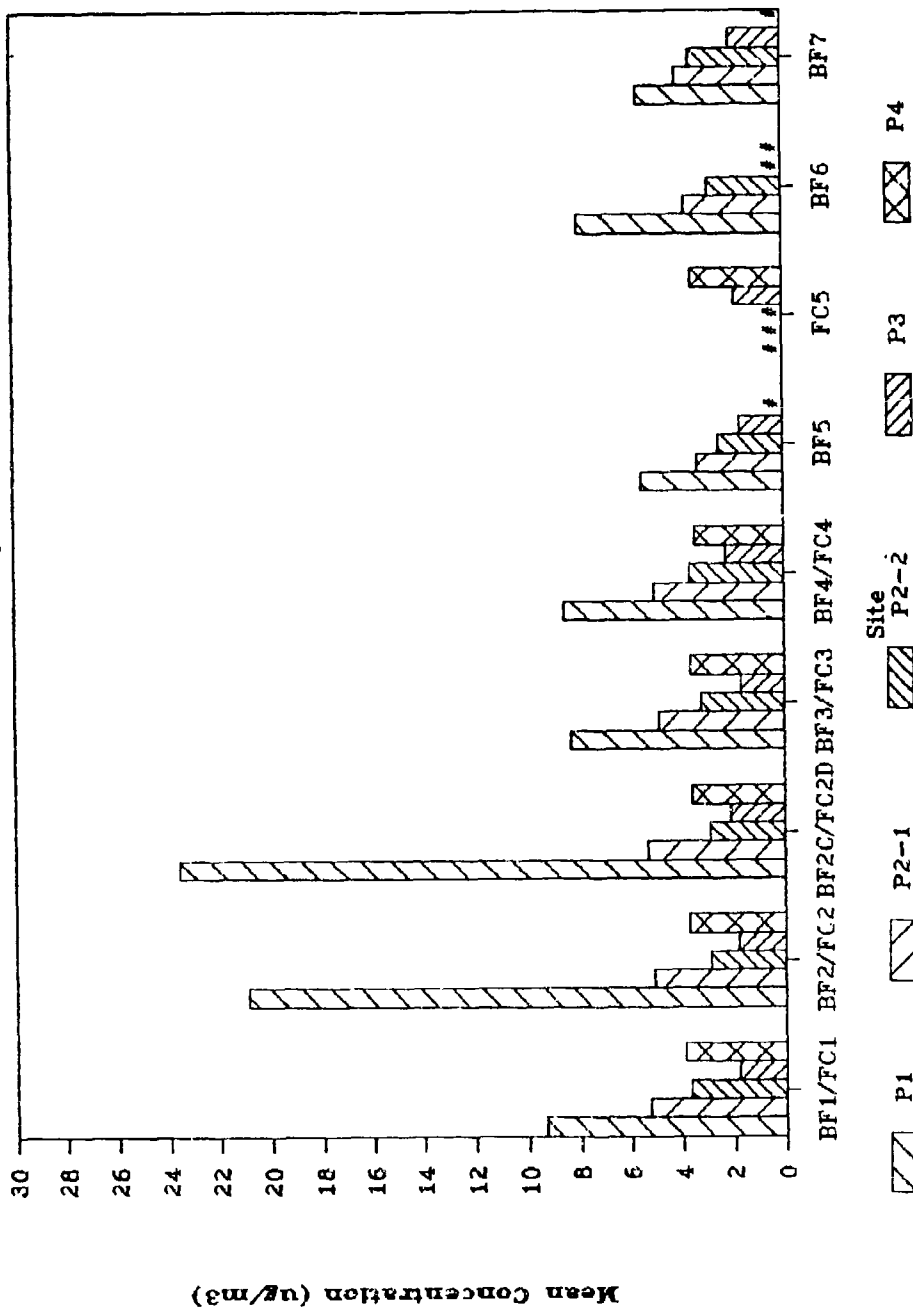
Figure 46-10

* No Samples Taken During this Phase
* Not Detected During this Phase

Dimethyl Disulfide Results by Phase

CMP AR FY90

Toluene Results By Phase



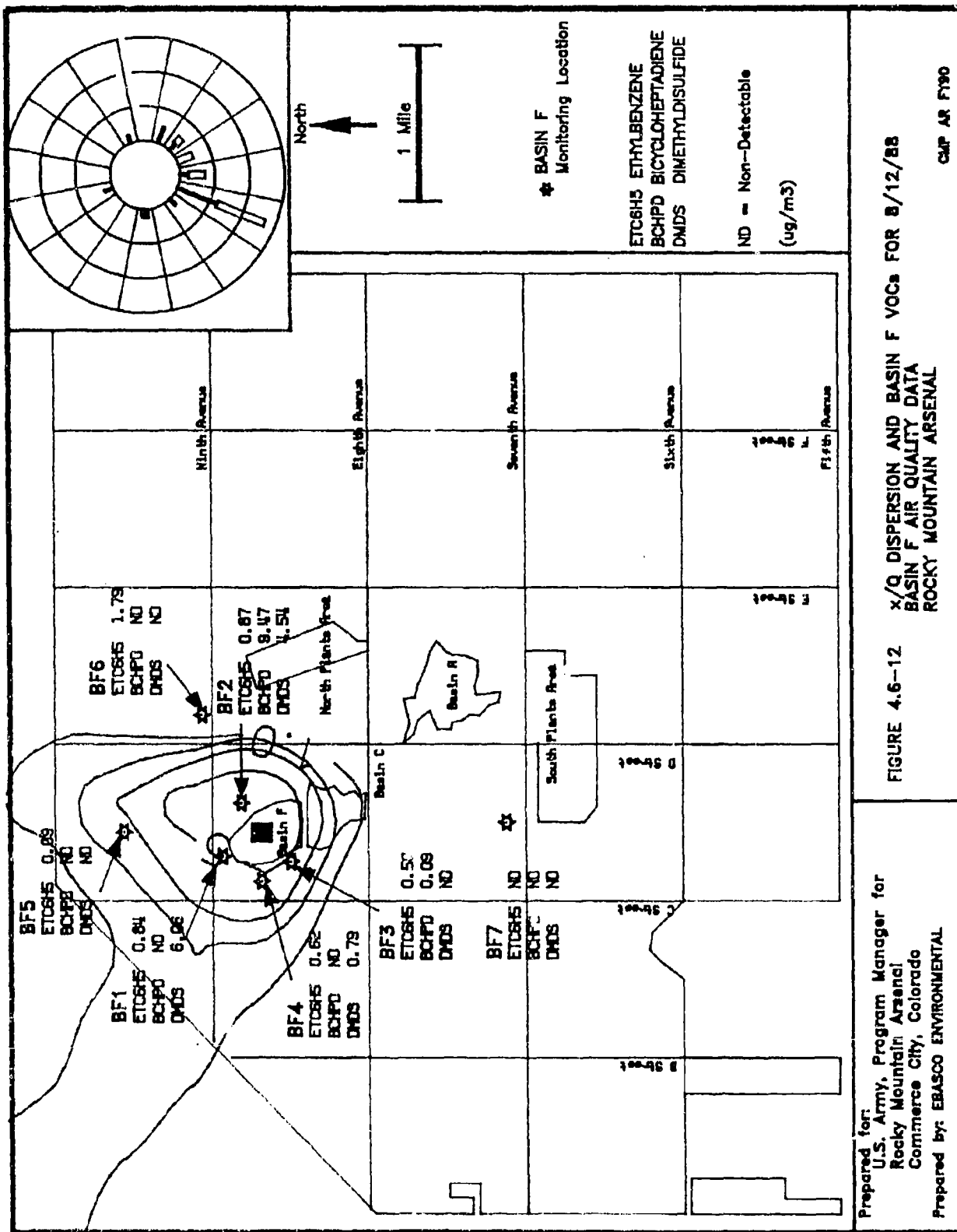
* No Samples Taken During this Phase
 * Not Detected During this Phase

Prepared for :
 U.S. Army Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by :
 R.L. Stollar & Associates, Inc.
 Ebasco Services, Inc.

Figure 4.6-11

Toluene Results by Phase

CMP AR FY90



Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: EBASCO ENVIRONMENTAL

FIGURE 4.6-12

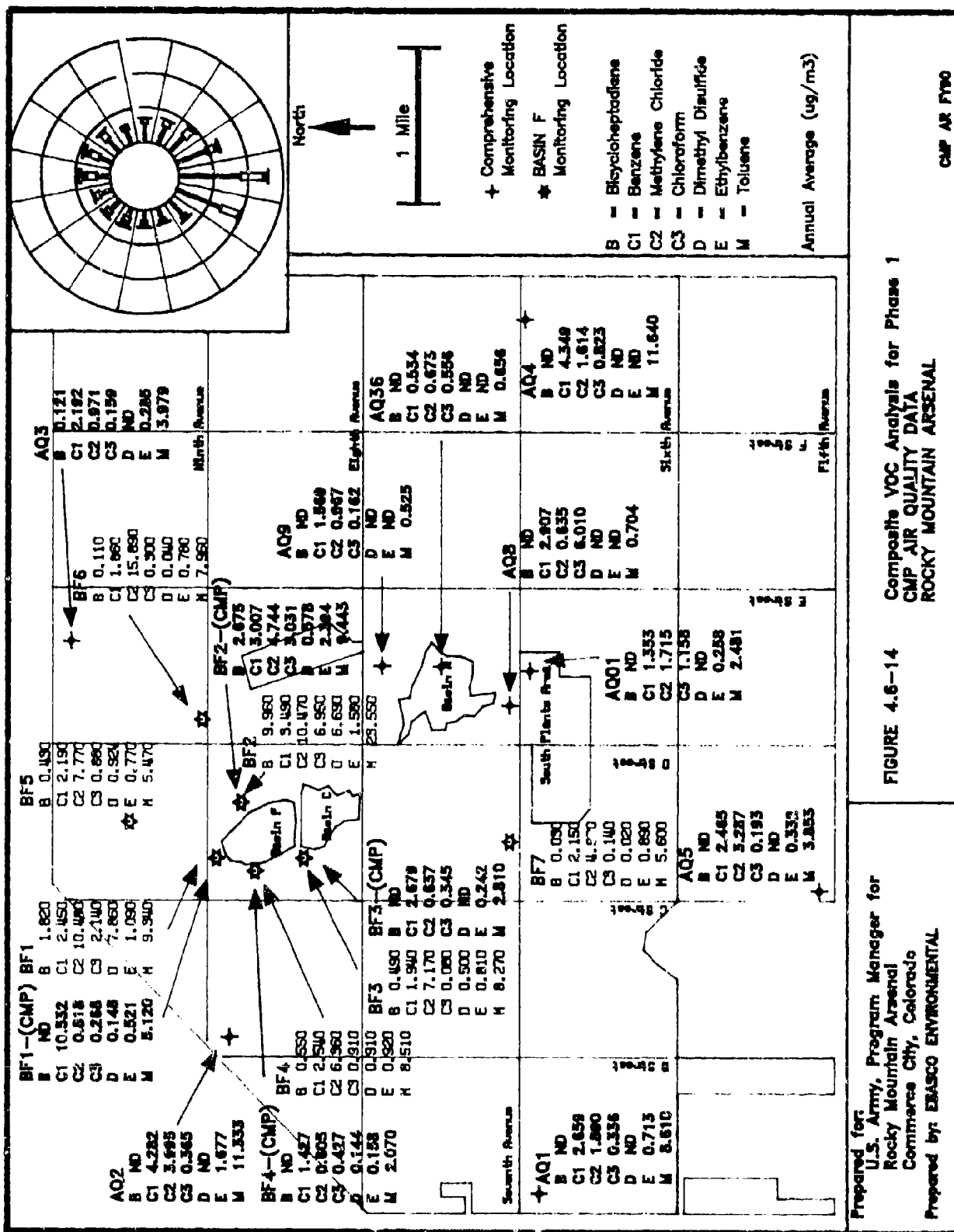
X/Q DISPERSION AND BASIN F VOCs FOR 8/12/88
 BASIN F AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

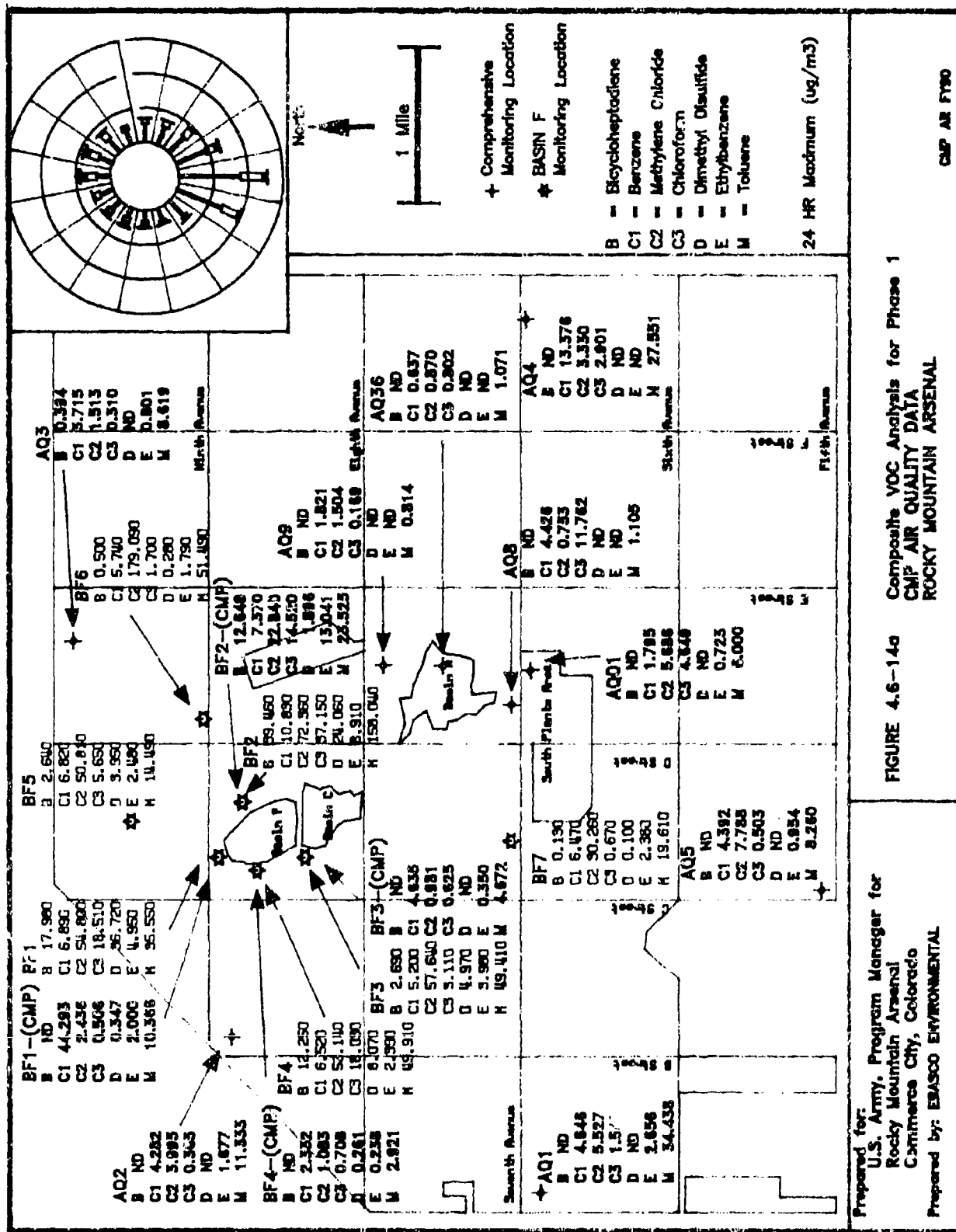
CMP AR F190

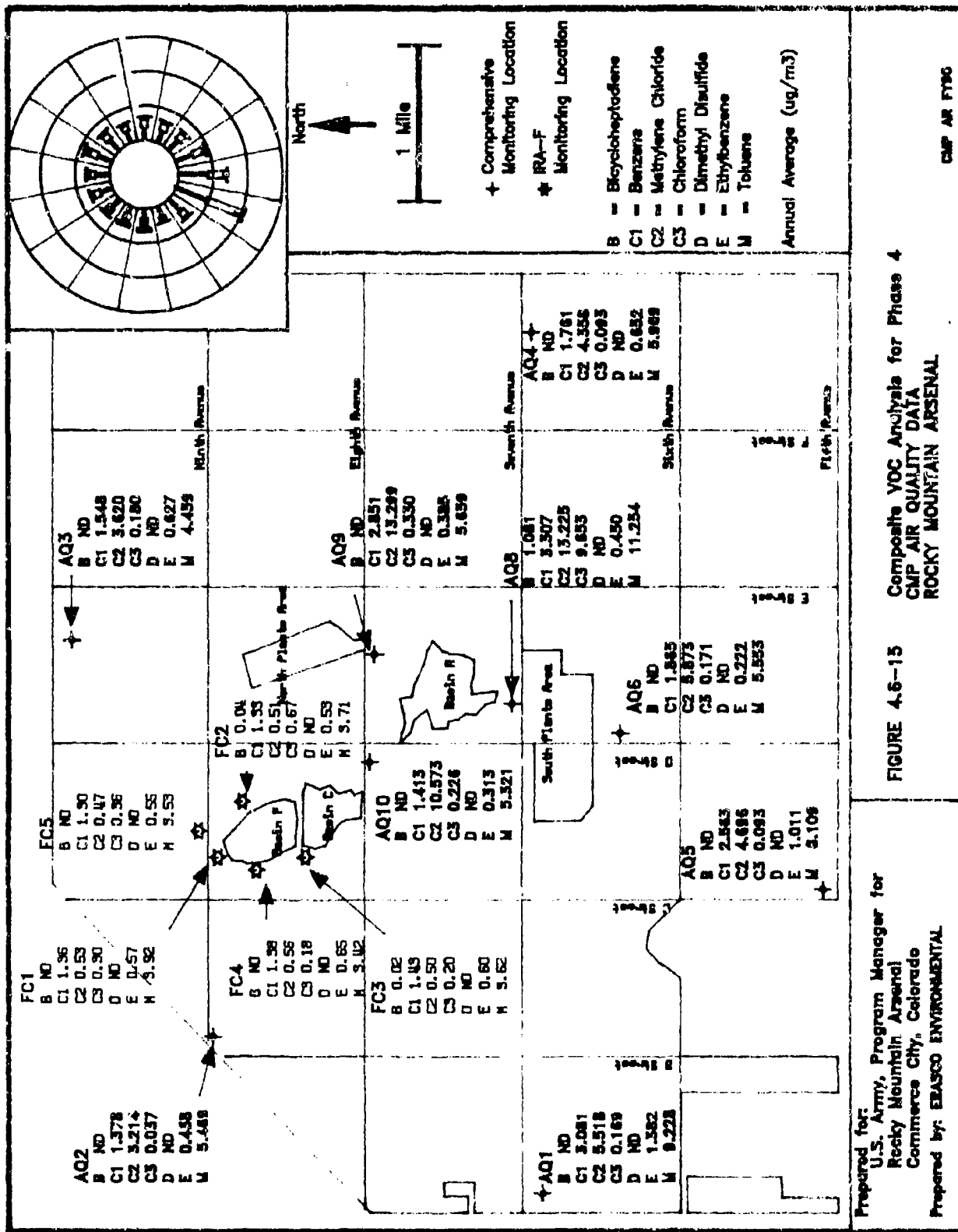
day were moderate and variable, but predominantly from the south. The maximum temperature was 80°F. There were no detectable amounts of dimethyl disulfide or bicycloheptadiene during the sample period, indicating that Basin F was not a source of these compounds on this day. The pattern of ethylbenzene shows that the concentrations at all sites were roughly 50 percent lower than on the Phase 1 day. From these typical day results, it appears that while Basin F was a likely source of VOCs during the remediation effort, it was not nearly as strong a source, if at all, during the post-remediation period.

4.6.3.3 Combined CMP and Basin F Data Analyses

Individual CMP and Basin F VOC monitoring data for the phases of the remedial and post-remedial monitoring programs were shown in Tables 4.6-3 and 4.6-4. Figures 4.6-14 through 4.6-15A provide illustrations of all available average and 24-hour maximum VOC data across the Arsenal complex for the Phase 1 remedial period and the Phase 4 post-remedial period. CMP data collected in the vicinity of Basin F are shown next to the Basin F data on these figures and printed in blue. Since samples were collected for only two events at the Basin F sites under the CMP in FY90, only the IRA-F results are shown in Figures 4.6-15 and 4.6-15A. The wind roses reflecting likely dispersion patterns are also shown in these figures. As noted from the previous discussions, the data show impacts for certain VOC compounds including benzene, chloroform, ethylbenzene, toluene, and dimethyl disulfide adjacent and immediately downstream from Basin F during the Phase 1 period. Further downstream, impacts were minimal and representative of the regional levels effecting the Arsenal. It appears from the data that Basin F VOC impacts were localized close to remediation activities. During the post-remedial Phase 4 period (Figures 4.6-15 and 4.6-15A), the impacts decreased for most of the VOC components, and concentrations at all CMP and IRA-F monitoring sites appeared to be normal baseline levels. Table 4.6-5 summarizes maximum average and maximum 24-hour concentrations for the CMP, Basin F, and IRA-F programs throughout the 31-month CMP monitoring period. This includes data for RIFS Sites 1 and 2 (see FY89 Air Quality Data Assessment Report). It is noted that RIFS Site 2 was located approximately one-half mile north of the Arsenal's northern boundary.





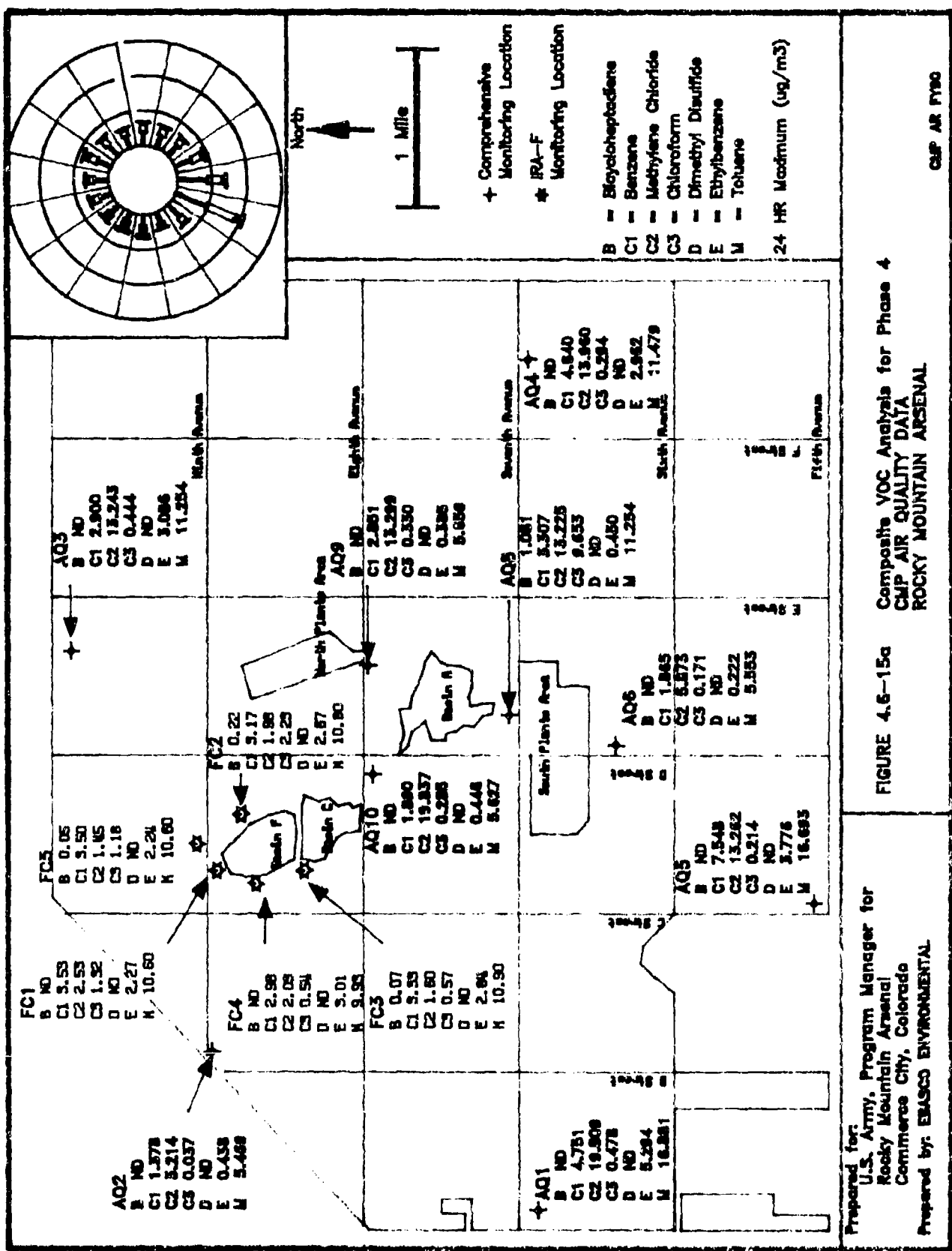


Prepared for:
U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by: EDASCO ENVIRONMENTAL

FIGURE 4.6-15

Composite VOC Analysis for Phase 4
CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

CMP AIR F190



Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: EIASCO ENVIRONMENTAL

FIGURE 4.6-15a

Composite VOC Analysis for Phase 4
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AIR FY80

Table 4.6-5 Maximum Concentrations and Locations of Volatile Organic Compounds
(in $\mu\text{g}/\text{m}^3$)

VOC	Maximum Long-Term Average	Location	Phase	Maximum 24-Hour Concentration	Location	Phase
1,1,1-Trichloroethane	10.53	BF4	P1	72.54	BF1	P1
1,1,2-Trichloroethane	0.46	BF2	P2-S2	4.00	BF2	P2-S2
1,1-Dichloroethane	0.14	CMP/BF3	P1	0.27	CMP/BF3	P1
1,2-Dichloroethane	0.49	AQ5	P2-S2	3.80	RIFS2	P2-S1
Bicycloheptadiene	9.96	BF2	P1	39.46	BF2	P1
Benzene	10.53	CMP/BF1	P1	44.29	CMP/BF1	P1
Carbon Tetrachloride	1.99	RIFS2	P2-S1	9.76	RIFS2	P1
Methylene Chloride	24.01	AQ5	P3	433.69	BF3	P2-S1
Chloroform	6.95	BF2	P1	37.15	BF2	P2-S2
Chlorobenzene	0.47	CMP/BF2	P1	2.53	CMP/BF2	P1
Dibromochloropropane	2.90	CMP/BF2	P1	17.04	CMP/BF2	P1
Dicyclopentadiene	4.53	BF2	P1	29.12	BF2	P1
Dimethyl Disulfide	7.86	BF1	P1	36.72	BF1	P1
Ethylbenzene	2.39	CMP/BF2	P1	13.04	CMP/BF2	P1
Toluene	23.55	BF2	P1	158.04	BF2	P1
Methylisobutylketone	0.47	AQ6	P3	1.13	FC4	P4
N-Nitrosodimethylamine	ND					
Dimethylbenzene	3.06	RIFS2D	P2-S1	8.03	RIFS2D	P2-S1
Trans-1,2-Dichloroethane	0.02	BF7	P2-S1	0.06	FC3	P4
Tetrachloroethene	5.29	BF1	P2-S2	24.02	BF1	P2-S2
Trichloroethene	6.98	BF1	P2-S2	40.43	BF1	P2-S2
Xylene	8.57	BF2	P1	49.91	BF2	P1

Note: Data from both within and above the certified range are summarized here.
Long-term refers to averages by phase.

- P1 = Phase 1
- P2-S1 = Phase 2-Stage 1
- P2-S2 = Phase 2-Stage 2
- P3 = Phase 3
- P4 = Phase 4

4.6.4 ADDITIONAL VOC MONITORING CONSIDERATIONS

4.6.4.1 Seasonal VOC Impacts

The CMP VOC high event program was designed to select monitoring periods when maximum emissions were anticipated in the vicinity of potential RMA source locations. The criteria of warm temperatures and light winds appeared to be the most favorable conditions for the release of volatile organics from soil surrounding potentially contaminated areas, especially during remediation activities. This was the case during the intense Basin F cleanup effort, when CMP monitors immediately downwind from Basin F measured peak levels of several compounds that appeared to be indigenous to the area (or related to remediation or construction activities). These compounds included 1,2-dichloroethane, bicycloheptadiene, benzene, chloroform, chlorobenzene, dicyclopentadiene, dimethyl disulfide, ethylbenzene, and xylene. During the post-remediation period, however, there was a substantial decrease in these ambient concentrations. There was also a shift in the location of maximum values from the Basin F area to the Arsenal perimeter, as well as a change in the optimum period for measuring peak VOC concentrations.

It was anticipated, at the outset of the CMP, that summertime high event monitoring, when temperatures are warmest and VOCs are more readily released into the atmosphere, would provide the highest VOC concentrations. In retrospect, this has not been the case. Some VOCs were measured at higher levels in the vicinity of Basin F during the summer 1988 (Phase 1) remediation period. However, many individual VOCs have been measured at relatively high levels (with respect to the overall database) during all seasons of the year. Table 4.6-6 shows the average seasonal distribution of VOCs for the combined 31-month CMP period (three spring and summer seasons and two fall and winter seasons). The summer periods include high events for each of the three years VOC data were collected. It is interesting that many of the highest concentrations were measured in the fall and, to some extent, winter, while the lowest concentrations for some analytes were measured in the spring and summer. This suggests that urban influences may have been dominant and that many VOCs have been transported into the Arsenal from the metropolitan area, especially during fall and winter intense inversion and brown cloud conditions. There is, however, considerable variability in the data at individual monitoring sites; for example the highest average levels of methylene chloride and chloroform were measured during the summer period. It is also noted that many of the compounds associated with Basin F remediation activities such as methylene chloride, chloroform, 1,2-dichloroethane, bicycloheptadiene and toluene that measured highest short-term levels during the

Table 4.6-6 Combined Seasonal Average VOC Concentrations (in $\mu\text{g}/\text{m}^3$) (FY88, FY89, and FY90)

Season	111TCE	TCE112	DCLE11	DCLE12	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
Winter	AQ1	1.007	*	*	*	1.394	0.767	3.251	0.180	*	*
	AQ3	1.010	*	*	*	0.931	0.384	1.303	0.105	*	*
	AQ4	1.009	*	*	*	0.930	0.768	1.302	0.086	*	*
	AQ5	1.987	*	*	*	0.917	0.757	3.849	0.145	*	*
Spring	AQ1	1.424	*	*	*	2.181	0.370	2.212	0.072	*	*
	AQ2	0.934	*	*	*	1.584	0.490	1.390	0.038	*	*
	AQ3	1.105	*	*	*	0.948	0.482	1.058	0.042	*	*
	AQ5	2.040	*	*	*	1.315	0.521	2.692	0.045	*	*
Summer	AQ1	1.479	*	*	*	2.589	0.409	7.426	0.232	0.027	*
	AQ2	1.483	*	*	*	1.056	0.355	25.125	*	*	*
	AQ3	1.188	*	*	*	1.702	0.402	4.751	0.138	*	*
	AQ4	1.274	*	*	*	2.592	0.571	3.781	0.365	*	*
	AQ5	2.195	*	*	*	1.983	0.402	8.966	0.128	*	*
	AQ6	3.454	*	*	*	1.690	0.425	3.929	0.171	*	*
	AQ8	1.277	*	*	0.450	3.040	0.322	4.831	7.224	*	*
	AQ9	1.420	*	*	*	1.996	0.481	5.078	0.218	*	*
	AQ10	1.923	*	*	*	1.480	0.357	5.534	0.282	*	*
	AQ01	1.528	*	0.044	0.108	1.231	0.478	3.159	0.872	0.040	*
	AQ02	4.115	*	*	*	1.898	0.337	13.281	0.208	*	*
	AQ23	2.305	*	0.089	*	1.415	0.585	7.578	0.584	*	*
	AQ26	1.215	*	0.045	0.533	2.886	0.415	8.195	0.737	0.164	0.574
	AQ35	1.323	*	0.097	*	1.220	0.401	1.372	0.080	*	*
	AQ36	1.648	*	*	0.101	0.916	0.725	4.991	0.865	*	*
Fall	AQ1	4.021	*	*	*	4.453	0.909	4.578	0.233	*	*
	AQ2	2.450	*	*	*	4.282	0.354	3.995	0.365	*	*
	AQ3	2.640	*	*	0.035	2.696	0.670	2.217	0.377	*	*
	AQ4	3.521	*	*	*	4.640	0.996	2.208	0.294	*	*
	AQ5	6.212	*	0.092	*	5.970	0.928	3.361	0.110	*	*

* All values below CRL

Table 4.6-6 Combined Seasonal Average VOC Concentrations (in $\mu\text{g}/\text{m}^3$) (FY88, FY89, and FY90) (continued)

Season	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	DMB12	T12DCE	TCLEE	TRC1XYLENE	
Winter	AQ1	*	0.885	4.427	*	*	0.982	*	1.308	0.116	0.869
	AQ2	*	0.319	3.882	*	*	0.462	*	0.564	0.040	0.871
	AQ3	*	0.275	3.325	*	*	0.408	*	0.393	0.040	0.870
	AQ4	*	0.437	4.367	*	*	0.484	*	1.935	0.039	1.285
Spring	AQ1	*	0.620	7.761	0.098	*	0.847	*	1.033	0.154	2.075
	AQ2	*	0.429	5.290	*	*	0.587	*	1.198	0.053	1.562
	AQ3	*	0.196	2.903	*	*	0.256	*	0.801	0.029	0.615
	AQ4	*	0.430	6.943	*	*	0.729	*	2.396	0.030	1.530
Summer	AQ1	*	0.617	9.085	0.112	*	0.844	*	0.807	0.107	2.414
	AQ2	*	0.187	6.842	*	*	0.257	*	0.133	0.081	0.598
	AQ3	*	0.252	3.907	0.076	*	0.326	*	0.528	0.082	1.421
	AQ4	*	0.269	8.933	*	*	0.371	*	0.490	*	1.170
	AQ5	*	0.508	6.295	0.100	*	0.588	*	1.404	0.084	1.670
	AQ6	*	0.228	4.029	0.318	*	0.285	*	0.569	0.082	0.870
	AQ8	*	0.203	4.221	*	*	0.221	*	0.359	0.137	1.424
	AQ9	*	0.183	2.237	*	*	0.224	*	0.346	0.120	0.848
	AQ10	*	0.223	4.999	*	*	0.247	*	0.593	0.097	0.673
	AQ01	0.053	0.246	3.917	0.086	*	0.319	*	0.519	0.051	0.849
	AQ02	*	0.452	5.651	0.251	*	0.501	*	1.336	0.124	1.331
	AQ23	*	0.371	7.036	*	*	0.496	*	0.664	0.165	1.103
	AQ26	0.381	0.662	4.717	0.054	*	0.328	*	0.632	0.183	1.430
	AQ35	*	0.451	3.490	*	*	0.518	*	0.676	*	1.374
	AQ36	*	0.216	3.675	0.076	*	0.343	*	0.539	0.254	1.248
Fall	AQ1	*	3.975	6.167	0.525	*	5.144	*	4.276	0.225	6.282
	AQ2	0.574	1.677	11.333	*	*	2.513	*	3.349	0.090	1.890
	AQ3	*	1.943	4.971	0.228	*	2.685	*	2.451	0.117	3.737
	AQ4	*	2.962	1.658	0.546	*	3.431	*	2.286	0.148	5.205
	AQ5	*	2.262	7.502	0.350	*	3.249	*	3.722	0.194	4.676

* All values below CRL

Basin F remediation period were averaged out over the 3-year, longer-term period (peak remediation period results are identified in the Phase 1 data shown in Tables 4.6-3 and 4.6-4).

Optimum monitoring and analysis of the VOC baseline at RMA requires consideration of seasonal worst-case meteorological factors as well as identifying potential impacts from both Arsenal and off-Arsenal sources. In future CMP efforts, the combined high event and IRA-F monitoring programs will be designed to capture maximum VOC concentrations impacting the Arsenal throughout the year and will include intense inversion days in fall and winter when metropolitan Denver impacts are transported in the direction of RMA. A better comparison can then be made between concentrations resulting from RMA remediation and concentrations at the Arsenal due to transport of emissions from urban VOC sources. A discussion of urban VOC emissions is provided in the following section.

4.6.4.2 Metropolitan Denver Area VOC Emissions

Many of the VOC levels measured at RMA interior locations during FY89 and FY90 were below Denver metropolitan and other urban ambient levels (refer to Tables 4.6-8 and 4.6-9 in the CMP FY89 report). Various compounds that were observed at higher levels during remediation activities decreased to typical urban background levels during the post-remedial monitoring periods. VOC levels measured at the RMA monitoring sites in FY90 may be partially attributed to some residual emissions in the Basin F area as well as emissions from the undisturbed areas of the South Plants, Basin A, and the North Plants. However, it would appear that VOC ambient levels measured at RMA during FY90 were, for the most part, dependent upon sources external to the Arsenal which impacted RMA under varying wind and inversion conditions.

Table 4.6-7 and Figure 4.6-16 show a number of VOC point sources identified by the Colorado Department of Health and the Citizen Fund Studies that may impact air quality of the Arsenal (CDH, 1990; Citizens Fund, 1990). The list includes emission sources in excess of 10 tpy and represents approximately 90 percent of all VOC emissions identified in Adams, Arapahoe and Denver counties. These sources include several major industries (Sundstrand Aviation, Pillow Kingdom, Gates Rubber Company, Samsonite Corporation, Conoco Denver Refinery) as well as many smaller industrial operations, chemical plants, paint manufacturing facilities, and large gasoline service stations. In addition, there are a large number of VOC point sources below 10 tpy in the metropolitan area, including dry cleaning establishments, paint stores, automobile shops, and small service stations. More importantly, many VOC emissions in the area are from mobile sources including gasoline and diesel burning vehicles, construction equipment, and aircraft emissions from nearby Stapleton

Table 4.6-7 Volatile Organic Compounds (VOC) Sources with Emissions of 10 TPY or More

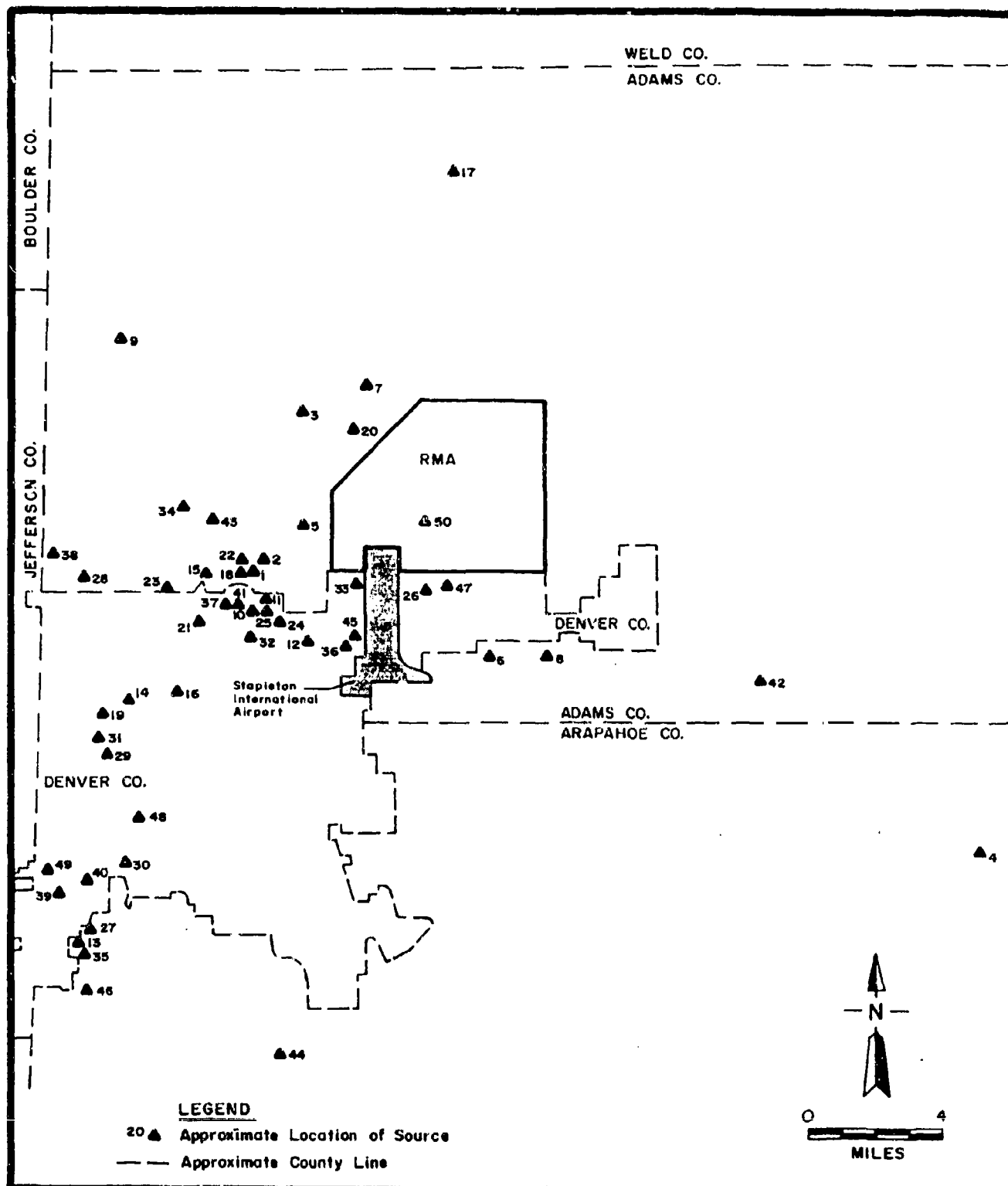
County	UTM/E	UTM/N	Plant Name	Emissions (tpy)	Percent Tri-County Total	Percent of State Total
Adams	504.5	4405.5	1 Conoco Inc.	3632	38.2	11.5
Adams	504.7	4405.8	2 Colorado Refining Co.	980	10.3	3.1
Adams	507.3	4410.3	3 Wyco Pipeline Co.	393	4.1	1.2
Arapahoe	581.8	4384.0	4 Bijou Recycling	305	3.2	1.0
Adams	507.5	4408.6	5 Rainbo Bread	194	2.0	0.6
Adams	516.0	4401.0	6 Chase Terminal	185	1.9	0.6
Adams	509.7	4413.3	7 Sinclair Marketing	137	1.4	0.4
Adams	520.6	4402.5	8 Mastercraft	125	1.3	0.4
Adams	499.9	4417.6	9 AT&T Information Systems	105	1.1	0.3
Denver	507.0	4403.5	10 Shafer Comm. Seating	99	1.0	0.3
Denver	507.5	4404.1	11 Mastercraft	99	1.0	0.3
Denver	506.3	4402.5	12 Pillow Kingdom Mfg.	99	1.0	0.3
Arapahoe	499.5	4386.7	13 The Vertical Company	98	1.0	0.3
Denver	440.7	5010.0	14 Advance Foam Plastic Inc.	96	1.0	0.3
Adams	504.9	4405.2	15 Diamond Shamrock Corp.	95	1.0	0.3
Denver	501.1	4400.7	16 Benjamin Moore & Co.	86	0.9	0.3
Adams	515.5	4424.5	17 Alltac Corp.	80	0.8	0.3
Adams	504.9	4405.2	18 Phillips Pipeline Co.	69	0.7	0.2
Denver	499.7	4398.4	19 Union Chemicals Division	60	0.6	0.2
Adams	510.0	4412.8	20 Oil & Solvent Process Co.	59	0.6	0.2
Denver	502.6	4402.8	21 Firestone Tire & Rubber	57	0.6	0.2
Adams	503.0	4406.2	22 PSCO Cherokee Plant	56	0.6	0.2
Adams	501.0	4404.5	23 Cobitco	56	0.6	0.2
Denver	506.7	4403.1	24 Energy Thermal Systems	55	0.6	0.2
Denver	507.9	4403.9	25 Ambassador Drapery Clnr.	54	0.6	0.2
Denver	511.5	4403.7	26 Scott's Liquid Gold	47	0.5	0.1
Arapahoe	499.6	4389.9	27 Sterling Stainless Tube	46	0.5	0.1
Adams	499.5	4405.6	28 Protective Const. Prod.	45	0.5	0.1
Denver	500.5	4398.7	29 Rocky Mountain News	43	0.5	0.1
Denver	500.6	4399.1	30 Gates Rubber Co.	39	0.4	0.1
Denver	499.6	4398.3	31 Komac Paint Company	38	0.4	0.1
Denver	504.8	4402.9	32 The Denver Post Corp.	35	0.4	0.1
Denver	510.3	4405.0	33 Natter Manufacturing co.	34	0.4	0.1
Adams	501.6	4409.2	34 Hughes and Company	34	0.4	0.1
Arapahoe	498.7	4389.3	35 Ashland Chemical Co.	33	0.3	0.1
Denver	509.0	4401.0	36 Combs - Gates Denver Inc.	33	0.3	0.1
Denver	503.2	4404.1	37 Power Assist Co. Inc.	33	0.3	0.1
Adams	497.5	4406.5	38 Conservation Services	31	0.3	0.1
Denver	498.0	4391.5	39 Import Auto Body	30	0.3	0.1
Denver	499.9	4394.3	40 Denver Industrial Sales	29	0.3	0.1
Denver	504.0	4402.9	41 American Coil Coating Inc.	29	0.3	0.1
Adams	524.7	4400.5	42 Colorado Interstate Gas	29	0.3	0.1
Adams	503.8	4406.5	43 Metro Denver Sewage Disp	29	0.3	0.1
Arapahoe	506.2	4380.8	44 Electromedics Inc.	27	0.3	0.1
Denver	509.9	4402.1	45 Western Airlines	27	0.3	0.1
Arapahoe	499.5	4386.7	46 Thomas Plating Co.	26	0.3	0.1
Denver	512.4	4404.2	47 Pease Industries Inc.	25	0.3	0.1
Denver			48 Conoco Inc., - Federal	25	0.3	0.1
Denver	497.5	4395.5	49 Conoco - Alameda	25	0.3	0.1
Denver	511.7	4404.2	Chemical Systems Techn.	24	0.3	0.1
Adams	499.7	4406.9	Western Paving Constr.	23	0.2	0.1

Table 4.6-7 Volatile Organic Compounds (VOC) Sources with Emissions of 10 TPY or More
(continued)

County	UTM/E	UTM/N	Plant Name	Emissions (tpy)	Percent Tri-County Total	Percent of State Total
Denver	500.1	4402.6	Brannan Sand and Gravel	19	0.2	0.1
Arapahoe	520.1	4395.6	U.S. Govt. Buckley Base	19	0.2	0.1
Denver	507.1	4402.7	Daralco Inc.	18	0.2	0.1
Denver	501.5	4400.8	City-Elite Cleaners	18	0.2	0.1
Denver			Conoco - Sheridan Blvd.	18	0.2	0.1
Denver	497.9	4403.5	Exxon Corp. - Federal	17	0.2	0.1
Denver	504.2	4397.3	Exxon Corp. - Colorado	17	0.2	0.1
Denver	505.5	4292.5	Exxon Corp. - S. Colorado	17	0.2	0.1
Denver	500.8	4401.1	B-D Chemical Co.	17	0.2	0.1
Denver	511.9	4402.1	Kwal Paints Inc.	17	0.2	0.1
Denver	512.4	4402.0	Frito Lay Inc.	17	0.2	0.1
Adams	497.9	4410.0	Exxon Corp. - Westminster	17	0.2	0.1
Adams	511.2	4398.8	Exxon Corp. - Aurora	17	0.2	0.1
Adams	494.7	4405.2	Precision Plastics Corp.	17	0.2	0.1
Adams	544.5	4405.5	National By-Products	16	0.2	0.1
Adams	525.1	4414.8	Koch Hydrocarbon Co.	15	0.2	
Adams	505.5	4405.9	United Asphalt Inc.	15	0.2	
Adams	503.2	4415.4	Future Foam Corp.	15	0.2	
Arapahoe	501.0	4291.6	Total Petroleum-Arapahoe	15	0.2	
Denver	506.2	4404.3	H Holding Inc.	14	0.1	
Denver	501.1	4400.7	Benjamin Moore & Co.	12	0.1	
Denver	497.8	4293.2	Total Petroleum-Federal	12	0.1	
Denver	502.0	4404.0	Ardco	12	0.1	
Denver	504.5	4398.7	Paradise Cleaners	12	0.1	
Adams	515.0	4424.9	Sam Hill Oil Co.	12	0.1	
Adams	513.0	4402.2	Englander Companies Inc.	11	0.1	
Arapahoe	499.7	4387.8	Martin Shipper Supply	11	0.1	
Denver	501.1	4397.4	Richenbaugh Cadillac Co.	11	0.1	
Denver	507.8	4402.1	Esquire Valet	11	0.1	
Denver	505.9	4402.3	Kistler Graphics Inc.	11	0.1	
Denver	498.7	4398.7	Siegel Oil Company	11	0.1	
Denver	499.8	4390.9	PSCO - Arapahoe Plant	10	0.1	
Denver	499.1	4397.6	Old Western Paint Co.	10	0.1	
Denver	504.7	4398.7	Galaxie Auto Body	10	0.1	
Denver	500.1	4391.5	Maaco Auto	10	0.1	
Denver	504.0	4403.3	Southland Corp.	10	0.1	
Adams	496.0	4405.6	Industrial Chemicals Corp	10	0.1	
Adams	513.6	4408.3	50 RMA	2		
TRI-COUNTY TOTALS				9,501	90.9	
STATE TOTALS				31,708		26.4

Source: Colorado Department of Health EISPS Inventory, May 1990.

Legend: UTM/E = Universal Transverse Mecator east coordinate
UTM/N = Universal Transverse Mecator north coordinate
tpy = tons per year



Prepared for:

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.
Ebasco Services Inc.

Figure 4.6-16

VOC Sources with Emissions of
25 tpy or More in RMA Vicinity

Airport. It is estimated that nonstationary sources represent a significant portion of the total VOC emissions. Finally, not listed on the available inventories and not readily quantifiable are emissions from feedlot facilities north of the Arsenal.

Table 4.6-8 stratifies toxicity for Denver VOC sources according to health-related characteristics (Citizens Fund, 1990). It is difficult to characterize toxicity strictly by tonnage of emissions. Obviously some constituents react differently in ambient air and represent greater toxicity hazards than others. Metropolitan Denver VOC emission sources in Table 4.6-9 are classified by the number of releases to the air and the VOC components of release. The categorizations shown in Tables 4.6-8 and 4.6-9 were prepared by the Citizens Fund from disclosures individual companies are required to file with the EPA under Title III of SARA. CMP did not validate these toxic release and toxic substance classifications. The purpose of providing these data is to indicate the broad scope of potentially toxic substances that comprise the metropolitan Denver area and may impact RMA air monitoring sites.

Many compounds from the above sources were most likely detected at RMA sites during VOC sampling. Several of the sources such as the Scott's Liquid Gold Company and the Oil and Solvent Process Company are within 2 miles of the Arsenal boundary. Because of the large number of stationary and mobile sources, however, it is difficult to delineate direct impacts on the Arsenal from individual point sources. Nevertheless, RMA monitoring results showed that many maximum VOC values were measured at perimeter sites with prevailing winds blowing onto the Arsenal from potential external source locations. On a case-by-case basis, high event monitoring showed that the highest VOC levels for specified VOC parameters occurred at perimeter sites AQ1, AQ3, AQ4, and AQ5. Several of these events have been previously discussed in Section 4.6.2. A summary of the results with respect to potential off-Arsenal upwind VOC emission sources is provided below.

On December 19, 1989, the wind direction was from the south through west-northwest with an average speed of 13 mph during the monitoring period. Maximum levels of a number of compounds sampled during this post-remediation monitoring period including 1,1,1-trichloroethane, benzene, ethylbenzene, carbon tetrachloride, dimethylbenzene, and xylene were measured on this day at all four perimeter stations. In fact, the highest concentrations of 1,1,1,-trichloroethane ($7.161 \mu\text{g}/\text{m}^3$), carbon tetrachloride ($1.169 \mu\text{g}/\text{m}^3$), and dimethylbenzene ($5.870 \mu\text{g}/\text{m}^3$) ever measured during any phase of the CMP occurred on this day (see Section 4.6.2.1 and Figure 4.6-1).

Table 4.6-8 Total Number of Releases of Toxic Chemicals by Facility and Toxicity for Denver and Adams Counties

Facility	Carcinogen	Heritable Mutagen	Developmental Toxin	Reproductive Toxin	Acute Toxin	Chronic Toxin	Neurotoxin
A.B. Hirschfield Press Inc.	0	0	27000	27000	0	27000	0
Alltac Corp.	0	0	63929	63929	0	1500	1500
Ardco Corp.	0	0	15470	15470	0	15470	15470
Asarco Inc., Globe Plant	0	0	0	0	502	502	0
Atlas Energy Products	0	0	0	0	0	0	0
Benjamin Moore & Co.	0	0	0	0	0	106	0
Boyles Galvanizing Co.	0	0	0	0	56306	56306	0
Chemical & Metal Ind. Inc.	75750	0	75750	75750	55150	21600	0
Chemrex Inc.	30300	0	0	0	0	0	0
Cobitco Inc.	0	0	0	0	47	47	0
Colorado Refining Co.	11851	0	24839	24839	28	19783	0
Conoco Denver Refinery	6875	0	65240	65240	396	62417	4586
Cryenco	0	0	16780	16780	0	0	0
Dixie Petro-Chem Inc.	0	0	0	0	500	500	0
E.R. Carpenter Co.	0	0	19800	19800	0	0	0
Gates Rubber Co.	7100	0	127300	127300	0	7100	0
Jackson Ice Cream Co.	0	0	0	0	3500	3500	0
Koppers Ind. Inc.	66	0	0	0	0	648	0
Kwal-Howells Inc.	0	0	0	0	0	500	0
Mesa Fiberglass Inc.	29880	29880	0	0	0	87550	0
Mid-America Plating Inc.	0	0	0	0	750	500	0
Modine Western-Rocky Mt.	0	0	112	112	0	0	0
NER Data Products, Inc.	0	0	32697	32697	0	0	0
Pepsi-Cola Bottling Co.	0	0	0	0	0	0	0
Pillow Kingdom	0	0	220592	220592	0	125277	52802
Prokrete In. Prochem Tech	0	0	53237	53237	0	11515	11515
Protecto Wrap Co.	0	0	1481	1481	0	1481	0
Redfield Riflescopes Inc.	0	0	150	150	0	150	0
Republic Paperboard Co.	0	0	44000	44000	0	0	0
Safeway Milk Plant	0	0	0	0	110	110	0
	0	0	0	0	0	0	0

Table 4.6-8 Total Number of Releases of Toxic Chemicals by Facility and Toxicity for Denver and Adams Counties (continued)

Facility	Carcinogen	Heritable Mutagen	Developmental Toxin	Reproductive Toxin	Acute Toxin	Chronic Toxin	Neurotoxin
Samsonite Corp.	0	0	119912	119912	0	3917	3917
Sashco Inc.	0	0	250	250	0	0	0
Sashco Inc.	0	0	0	0	0	1000	0
Scott's Liquid Gold Inc.	0	0	1500	1500	0	0	0
Shafer Commercial Seating	112	112	45115	45181	46	43394	22046
Stanley Aviation Corp.	21700	0	45250	45250	0	21700	0
Sundstrand Aviation Oper.	67952	0	269267	269267	11341	147601	1492
Thompson Pipe & Steel Co.	0	0	13400	13400	0	13400	0
W.J. Whatley Inc.	2363	2363	0	0	0	52671	0
Whirlpool Kitchens Inc.	0	0	128539	128539	0	87532	72640
Whittaker Power Storage	0	0	0	0	750	750	0
Wright & McGill Co.	802	0	802	802	260	802	0

Source: "Poisons in Our Neighborhoods, Toxic Pollution in Colorado." Citizens Fund, Washington, D.C., Appendix VIII, June 1990.

Table 4.6-9 Releases of Toxic Chemicals for Denver and Adams Counties

Facility	Releases to Air	% Of Total for County	County	Major Components of Release
Sundstrand Aviation Oper.	314343	27.78	Denver	111TCE, freon113, Tetrachloroethylene, et al.
Pillow Kingdom	284866	25.17	Denver	Toluene, 111TCE, MEK, Xylenes, acetone, et al.
Gates Rubber Co.	123130	10.88	Denver	Toluene, 111TCE, Tetrachloroethylene, zinc
Samsonite Corp.	119912	10.60	Denver	111TCE, MEK
Conoco Denver Refinery	106130	20.82	Adams	Propylene, xylenes, toluene, Ethylene, et al.
Whirlpool Kitchens Inc.	96114	18.85	Adams	Toluene, MIBK, xylenes
Shafer Commercial Seating	74235	6.56	Denver	Xylene, toluene, MIBK, Methanol, 111TCE, et al.
Mesa Fiberglass Inc.	67050	13.15	Adams	Acetone, styrene
Alltac Corp.	62429	12.25	Adams	Toluene, MEK
Pillow Kingdom	53237	4.70	Denver	Toluene, 111TCE, MEK
W.J. Whatley Inc.	52671	10.33	Adams	Acetone, styrene
Colorado Refining Co.	47134	9.25	Adams	Cyclohexane, benzene, Xylenes, toluene, et al.
Stanley Aviation Corp.	45250	8.88	Adams	111TCE, tetrachloroethylene
Redfield Riflescopes Inc.	44250	3.91	Denver	111TCE, aluminum
Chemrex Inc.	30300	5.94	Adams	Dichloromethane
A.B. Hirschfield Press Inc.	27000	2.39	Denver	Xylenes
NER Data Products, Inc.	26732	2.36	Denver	Toluene, 111TCE
E.R. Carpenter Co.	19800	1.75	Denver	111TCE
Ardco Corp.	15470	1.37	Denver	MEK
Cyrenco	9300	0.82	Denver	111TCE
Thompson Pipe & Steel Co.	8600	0.76	Denver	Xylenes
Chemical & Metal Ind. Inc.	2500	0.22	Denver	1122Tetrachloroethane, Antimony, CCL4, et al.
Koppers Ind. Inc.	2400	0.21	Denver	Naphthalene, dibenzofuran, Anthracene
Boyles Galvanizing Co.	1990	0.39	Adams	Hydrochloric acid, zinc
Asarco Inc., Globe Plant	1703	0.15	Denver	Cadmium, lead, sulfuric acid, Zinc, et al.
Jackson Ice Cream Co.	1000	0.09	Denver	Ammonia
Scott's Liquid Gold Inc.	750	0.07	Denver	111TCE
Mid-America Plating Inc.	750	0.07	Denver	Hydrochloric acid, nitric Acid, sulfuric acid
Whittaker Power Storage	500	0.04	Denver	Sulfuric acid
Dixie Petro-Chem Inc.	500	0.10	Adams	Ammonia, chlorine
Kwal-Howells Inc.	250	0.02	Denver	Ethylene glycol
Atlas Energy Products	250	0.02	Denver	Phenylisocyanate
Sashco Inc.	250	0.05	Adams	Toluene
Prokrete Inc. Prochem Tech	161	0.01	Denver	Xylenes
Benjamin Moore & Co.	153	0.01	Denver	Ethylene glycol, zinc
Protecto Wrap Co.	150	0.01	Denver	Xylenes

Table 4.6-9 Releases of Toxic Chemicals for Denver and Adams Counties (continued)

Facility	Releases to Air	% Of Total for County	County	Major Components of Release
Modine Western-Rocky Mt.	102	0.01	Denver	Copper
Cobitco Inc.	47	0.00	Denver	Hydrochloric acid
Republic Paperboard Co.	10	0.00	Adams	Hydrochloric acid
Pepsi-Cola Bottling Co.	0	0.00	Denver	--
Sashco Inc.	0	0.00	Adams	--
Safeway Milk Plant	0	0.00	Denver	--
Wright & McGill Co.	0	0.00	Denver	--
Total for Denver County	1131591			
Total for Adams County	509828			

Source: "Poisons in Our Neighborhoods, Toxic Pollution in Colorado." Citizens Fund, Washington, DC, Appendices II and IX, June 1990.

On June 27, 1990, the winds were mainly from the south-southwest averaging 11 mph. The greatest impacts occurred at perimeter Station AQ1, where the maximum level of toluene ($16.881 \mu\text{g}/\text{m}^3$) was measured for the Phase 4 period. High levels of ethylbenzene were also measured on this day at Stations AQ1 and AQ5 (see Section 4.6.2.2 and Figure 4.6-2).

On July 18, 1990, the dominant wind direction was from the west-southwest with an average speed of 12 mph. Consistently high levels of methylene chloride were measured at all four perimeter stations, with values ranging from 13.244 to $19.810 \mu\text{g}/\text{m}^3$ (see Section 4.6.2.3 and Figure 4.6-3).

Winds were mainly from the south-southwest on August 2, 1990, with an average speed of 9 mph. The greatest impacts occurred at perimeter Stations AQ1 and AQ5, where consistently high levels of benzene ($6.281 \mu\text{g}/\text{m}^3$), chloroform ($0.478 \mu\text{g}/\text{m}^3$), tetrachloroethene ($5.894 \mu\text{g}/\text{m}^3$), and xylene ($8.741 \mu\text{g}/\text{m}^3$) were measured (see Appendix E for all sample data).

It is not the intention of this assessment to minimize potential toxic emission sources at RMA resulting from prior activities, from recent remedial actions, or from current residual sources. A concerted effort was made to identify such sources through the intensive CMP and IRA-F monitoring programs. Nevertheless, in order to interpret the database, it is important to identify those emission constituents that contribute most to the database.

4.6.5 SUMMARY OF RESULTS AND ASSESSMENT OF VOC TOXICITY LEVELS

In order to assess the significance of measured VOC concentrations relative to health standards and guidelines, a literature search was conducted using sources similar to those identified in the metals assessment. Again this was necessary because the state of Colorado has not published air toxic regulations or promulgated standards. Guideline values were then compared with maximum concentrations measured for the CMP, Basin F, IRA-F and RIFS programs.

The tabulation of guideline concentrations is presented as Tables 4.6-10 and 4.6-11 for each target VOC for the remedial period (Phases 1 and 2) and the post-remedial period (Phases 3 and 4). The name and chemical abstract number is presented, along with TLV and TLV/420 concentrations. The value TLV/420 is used because this value is employed by many states in air toxic regulations as an annual concentration guideline "not to be exceeded." The next two columns of information are derived from the Superfund Health Risk Evaluation document (USEPA, 1986), and correspond to acceptable subchronic and chronic unit risk values (10^{-6} risk). The EPA document defines subchronic

Table 4.6-10 RMA Target Volatile Organic Compounds (VOC) Comparison to Health Guidelines for Phases 1 and 2

Target Name	CAS #	Short-term			Typical Guidelines		RMA Phases 1 and 2				RMA CMP Boundary Evaluation**			
		TLV (ppm)	TLV/420 (µg/m ³)	ADI	1 Yr Avg ADI	Annual (µg/m ³)	Maximum Conc.*		% of Guideline		Max. Boundary Conc. (µg/m ³)		% of Guideline	
							24-Hour	Long-Term	24-Hr	Long-Term	24-Hr	Long-Term	24-Hr	Long-Term
1,1,1-Trichloroethane	71-55-6	350	4948	38500	22050	38000	72.54	10.53	<1	<1	5.26	2.45	<1	<1
1,1,2-Trichloroethane	79-00-5	10	141	225	483	107	4.00	0.46	2	<1	ND	ND	ND	ND
1,1-Dichloroethane	75-34-3	200	2105	4830			0.27	0.14			ND	ND	ND	ND
1,2-Dichloroethane	107-06-2	10	105				3.80	0.49			0.50	0.50		
Bicycloheptadiene	121-46-0						39.46	9.96			0.39	0.12		
Benzene	71-43-2	10	83	150		72	44.29	10.53	30	15	13.38	4.35	9	6
Carbon Tetrachloride	56-23-5	5	82	300		0.67	9.76	1.99	2	>100	2.28	0.91	<1	>100
Methylene Chloride	75-09-2	50	452	7000		55.55	433.69	23.81	6	43	7.79	4.00	<1	7
Chloroform	67-66-3	10	126	250	35	0.43	37.15	6.95	15	>100	2.90	0.82	1	>100
Chlorobenzene	108-90-7	75	901	185.5	19.95		2.53	0.47			0.23	0.09		
Dibromochloropropane	96-12-8	0.001	0.025				17.04	2.90			ND	ND	ND	ND
Dicyclopentadiene	77-73-6	5	70.26	500			29.12	4.53	6		0.57	0.57	<1	
Dimethyl disulfide	624-92-0						36.72	7.86			ND	ND	ND	ND
Ethylbenzene	100-41-4	100	1127	3395	350		13.04	2.39	<1		2.66	1.68	<1	
Toluene	108-88-3	100	978	5250	5250	400	158.04	23.55	3	6	34.44	11.64	<1	3
Methylisobutyl ketone	108-10-1	50	531.46	175			0.51	0.10			0.24	0.08		
N-Nitrosodimethylamine	62-75-9						ND	ND	ND	ND	ND	ND	ND	ND
Dimethylbenzene	95-47-6	100	1126.70	3360	700	1450	8.03	3.06	<1	<1	4.42	2.51	<1	<1
Trans-1,2-Dichloroethene	156-60-5	200	2062	13000			0.05	0.02	1		ND	ND	ND	ND
Tetrachloroethene	127-18-4	50	882	3350	70	21	24.02	5.29	<1	25	3.92	3.35	<1	16
Trichloroethene	79-01-6	50	696	2700		2.439	40.43	6.98	1	>100	0.31	0.11	<1	5
Xylene	108-38-3	100	1126.70	3500	700	1450	49.91	8.57	1	<1	4.85	3.76	<1	<1

* In µg/m³.

** Data from both within and above the certified range are summarized here.

Legend: ADI = Acceptable Daily Intake

TLV = Threshold Limit Value

AIR-TBL2.90

Table 4.6-11 RMA Target Volatile Organic Compounds (VOC) Comparison to Health Guidelines for Phases 3 and 4

Target Name	CAS #	Short-term		Typical Guidelines (µg/m ³)	RMA Phases 3 and 4				RMA CMP Boundary Evaluation**										
		TLV (ppm)	TLV/420 (µg/m ³)		ADI	1 Yr Avg ADI	Subchronic	Chronic	Annual	Maximum Conc.*		Max. Boundary Conc. (µg/m ³)		% of Guideline					
										24-Hr	Long-Term	24-Hr	Long-Term	24-Hr	Long-Term	24-Hr	Long-Term		
																		% of Guideline	% of Guideline
1,1,1-Trichloroethane	71-55-6	350	4948	38500	22050	24500	38000	4.61	4.11	<1	<1	7.16	3.22	<1	<1				
1,1,2-Trichloroethane	79-00-5	10	141			225	107	0.06	0.02	<1	<1	ND	ND	ND	ND				
1,1-Dichloroethane	75-34-3	200	2105	4830	483	8100		0.05	0.01	<1		ND	ND	ND	ND				
1,2-Dichloroethane	107-06-2	10	105					0.25	0.10			0.18	0.08						
Bicycloheptadiene	121-46-0							1.08	1.08			ND	ND						
Benzene	71-43-2	10	83			150	72	3.76	3.31	2	5	7.55	3.08	5	4				
Carbon Tetrachloride	56-23-5	5	82			300	0.67	1.93	1.36	<1	>100	1.17	0.56	<1	84				
Methylene Chloride	75-09-2	50	452			7000	55.55	19.84	13.30	<1	24	60.10	24.01	1	43				
Chloroform	67-66-3	10	126		35	250	0.43	2.39	1.68	<1	>100	0.48	0.18	<1	42				
Chlorobenzene	108-90-7	75	901	185.5	19.95			0.11	0.03			ND	ND						
Dibromochloropropane	96-12-8	0.001	0.025					ND	ND			ND	ND						
Dicyclopentadiene	77-73-6	5	70.26			500		ND	ND	ND	ND	ND	ND	ND	ND				
Dimethyl disulfide	624-92-0							ND	ND			ND	ND						
Ethylbenzene	100-41-4	100	1127	3395	350	4350		3.99	0.65	<1		5.29	1.38	<1					
Toluene	108-88-3	100	978	5250	5250	5600	400	11.38	9.16	<1	2	16.88	9.23	<1	2				
Methylisobutyl ketone	106-10-1	50	531.46	175				1.13	0.25			1.04	0.26						
N-Nitrosodimethylamine	62-75-9							ND	ND			ND	ND						
Dimethylbenzene	95-47-6	100	1126.70	3360	700	4350	1450	1.00	0.74	<1	<1	5.87	1.82	<1	<1				
Trans-1,2-Dichloroethene	156-60-5	200	2062			13000		0.06	0.02	<1		ND	ND	ND	ND				
Tetrachloroethene	127-18-4	50	882	70	70	3350	21	6.34	1.34	<1	6	5.89	2.39	<1	11				
Trichloroethene	79-01-6	50	696			2700	2.439	1.52	0.61	<1	25	0.32	0.14	<1	6				
Xylene	108-38-3	100	1126.70	3500	700	4350	1450	7.09	3.53	<1	<1	9.52	3.88	<1	<1				

* In µg/m³.

** Data from both within and above the certified range are summarized here.

Legend: ADI = Acceptable Daily Intake

TLV = Threshold Limit Value

AIR-TBL2.90

exposures as those lasting 30 to 90 days; therefore, the subchronic concentration guidelines should be thought of as acceptable 30 to 90 day average concentrations. The chronic levels reflect a 1-year constant exposure. The next two columns of Tables 4.6-10 and 4.6-11 present "typical" state toxic guidelines, both for short-term (1 to 24-hour) and annual averages. There is a great deal of variability in air toxic guideline concentrations from state to state; therefore, in order to determine typical values, the median of all National Air Toxics Information Clearinghouse (NATICH) listed values was selected.

The next two columns show the 24-hour maximum and the average maximum values measured from either the CMP, Basin F, IRA-F, or RIFS programs. The VOC data for each phase were then compared to the appropriate guideline values. The 24-hour values were compared to the 24-hour guideline values; the maximum average values were compared to the maximum long-term guideline values.

The next two columns of Tables 4.6-10 and 4.6-11 show the percentage of the highest 24-hour maximum concentrations and the highest maximum average concentrations to the guidelines. An evaluation of these data should consider the fact that both the CMP and Basin F programs selected worst-case periods for sampling. The final columns of Tables 4.6-10 and 4.6-11 show the percentage of RMA boundary monitoring station maximum concentrations and provide a comparison to the guidelines.

A conservative approach is employed in this evaluation in order to identify potential areas of concern and the emphasis necessary in ongoing CMP activities. It is not the purpose of this study to provide a rigorous health risk assessment, but rather to provide data for such an assessment and to evaluate remedial progress over the long-term period of continuing cleanup activities. Consequently, this report summarizes two separate databases; that certified by PMRMA methods, and that which is either above the certified range or not certified by PMRMA. Results from the Basin F program, out-of-certified range data analyses, and nontarget data analyses substantially assisted in assessing remedial progress and in identifying future needs and requirements. These data, however, may not meet full specifications of PMRMA certification. All PMRMA certified and reviewed data, which consist of the majority of the CMP metals, VOC, SVOC and OCP data employed in this report, are provided in Appendices C, E, F and G. These data meet the most rigorous standards for quantification of the target analytes. The other data must be considered as less rigorous estimates of atmospheric concentrations, which can still be used for meaningful analysis and interpretation.

For the most part, even by applying a generalized and conservative approach, concentrations remained well below available toxic guidelines and standards even during the Phase 1 period. In several instances where a level of possible concern was identified, the post-remedial Phase 3 and 4 data show these concerns no longer exist.

A review of the CMP, Basin F, and IRA-F target analyte data results and potential toxic concerns for several pertinent compounds follows. Nontarget analyte data will be considered in Section 4.6.6.

Benzene - The highest short-term benzene level, $44.3 \mu\text{g}/\text{m}^3$, was measured on a CMP high event monitoring day, August 26, 1988, in the vicinity of BF1 (at the northern perimeter of Basin F). This was an anomalously high reading and one of the few occasions when a CMP monitor in the vicinity of Basin F measured higher levels than the Basin F program monitors. This concentration was 30 percent of the 24-hour typical guideline of $150 \mu\text{g}/\text{m}^3$. Maximum 24-hour benzene concentrations ranged from $0.64 \mu\text{g}/\text{m}^3$ to $13.4 \mu\text{g}/\text{m}^3$ at other CMP and Basin F monitoring stations. The second highest 24-hour level was at AQ4 at the southeast boundary of RMA. During FY90, the highest 24-hour benzene level was $3.761 \mu\text{g}/\text{m}^3$, recorded on a CMP high event day at Station FC4.

It appears from the data that baseline benzene concentrations were evenly distributed in the RMA vicinity, with short-term peaks occasionally reported as a result of cleanup or construction activities at Basin F and elsewhere; these include diesel emissions from trucks and other heavy equipment, both on and off the Arsenal.

The highest long-term benzene average, $10.5 \mu\text{g}/\text{m}^3$ at Station BF1-(CMP), was 15 percent of the long-term median typical guideline of $72 \mu\text{g}/\text{m}^3$ for toxic concern (See Table 4.6-12). Note again that this was based on worst-case averages, including one anomalously high measurement. The maximum Basin F long-term average was $3.97 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1 at BF1, or 6 percent of the guideline. The highest annual average during FY90 was $3.307 \mu\text{g}/\text{m}^3$ at AQ8, and was less than 5 percent of the long-term guideline.

Bicycloheptadiene - The highest 24-hour bicycloheptadiene level, $39.5 \mu\text{g}/\text{m}^3$, was measured under the Basin F monitoring program at BF2 on the northeast perimeter of Basin F. The next highest 24-hour measurement was only $18.0 \mu\text{g}/\text{m}^3$ at BF1. Bicycloheptadiene was a highly localized source in the vicinity of Basin F. The highest maximum average, $9.96 \mu\text{g}/\text{m}^3$ was also measured at BF2. The Basin F monitoring program measured levels of bicycloheptadiene that dropped off significantly from

the Basin F perimeter, especially in the post-remediation phases. CMP measurements were all well below those at the Basin F sites. There is no apparent toxic guideline for bicycloheptadiene.

Methylene Chloride - The maximum 24-hour methylene chloride value, $434 \mu\text{g}/\text{m}^3$, was measured at BF3 during Phase 2, Stage 2. Station BF6 reported a maximum 24-hour level of $179 \mu\text{g}/\text{m}^3$ during Phase 1, and BF2 reported a maximum value of $72.8 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 2. The maximum measured 24-hour concentration was 6 percent of the short-term guideline of $7000 \mu\text{g}/\text{m}^3$. During Phase 4, the 24-hour maximum methylene chloride level was $19.8 \mu\text{g}/\text{m}^3$ measured at AQ1.

Basin F was a localized source of methylene chloride, with downstream flow in the direction of BF3 and BF6. The maximum long-term average of methylene chloride was $24.0 \mu\text{g}/\text{m}^3$ at AQ5, or 43 percent of the long-term annual guideline of $55.55 \mu\text{g}/\text{m}^3$. Since this was an average of selected worst-case conditions, this assessment is conservative. Methylene chloride values fell off significantly with distance from Basin F. The CMP maximum levels ranged from $0.43 \mu\text{g}/\text{m}^3$ to $60.1 \mu\text{g}/\text{m}^3$ (at AQ5). Average values ranged from $0.43 \mu\text{g}/\text{m}^3$ to $24.0 \mu\text{g}/\text{m}^3$. Average values during Phase 4 continued to decrease, ranging from 1.37 to $13.3 \mu\text{g}/\text{m}^3$ at the CMP sites, and there appeared to be no on-site RMA source during that period.

Chloroform - The maximum 24-hour chloroform level, $37.1 \mu\text{g}/\text{m}^3$, was measured at Station BF2 during Phase 1. The next highest 24-hour chloroform level, $18.5 \mu\text{g}/\text{m}^3$, was measured at BF1. The long-term maximum average value, $6.95 \mu\text{g}/\text{m}^3$ was also measured at BF2 during Phase 1 and was greater than 100 percent of the typical annual guideline. Long-term averages at CMP sites ranged from 0.03 to $6.01 \mu\text{g}/\text{m}^3$. These data suggest that there were localized sources of chloroform in the vicinity of South Plants and BF2. During Phases 3 and 4, levels of chloroform decreased significantly.

The maximum 24-hour chloroform level, $37.1 \mu\text{g}/\text{m}^3$, was 15 percent of the guideline of $250 \mu\text{g}/\text{m}^3$; however, the maximum long-term average at BF2, $6.95 \mu\text{g}/\text{m}^3$, was 16 times higher than the annual typical guideline of $0.43 \mu\text{g}/\text{m}^3$. This guideline appears unrealistically low relative to other chloroform guidelines. The TLV/420 value is $126 \mu\text{g}/\text{m}^3$, and the ADI chronic long-term guideline is $35 \mu\text{g}/\text{m}^3$; consequently, the maximum long-term concentration, $6.95 \mu\text{g}/\text{m}^3$, was 6 and 17 percent of these respective guidelines.

Dimethyl Disulfide - A 24-hour maximum dimethyl disulfide level of $36.7 \mu\text{g}/\text{m}^3$ was measured at BF1 during Phase 1. The next highest value $24.1 \mu\text{g}/\text{m}^3$, was measured at BF2. The maximum

averages were $7.86 \mu\text{g}/\text{m}^3$, measured at BF1, and $6.69 \mu\text{g}/\text{m}^3$, measured at BF2. Both Basin F and CMP maximum and average values decreased to non-detectable after Phase 2, Stage 1.

Basin F appeared to be a localized source of dimethyl disulfide. The component drifted to the north under prevailing inversion flow, but levels also decreased significantly with distance. There were no dimethyl disulfide concentrations measured to the south of Basin F sites at CMP or Basin F monitoring stations. There are no suggested guideline values for dimethyl disulfide.

Ethylbenzene - A 24-hour maximum ethylbenzene level of $13.0 \mu\text{g}/\text{m}^3$ was measured at the CMP Station BF2 monitor during Phase 1. The second maximum 24-hour concentration of $8.97 \mu\text{g}/\text{m}^3$ was measured at the Basin F program BF4 station. The maximum long-term average value, $2.39 \mu\text{g}/\text{m}^3$, was also measured at CMP Station BF2 and was less than 1 percent of the annual guideline. Ethylbenzene values at other sites decreased with distance from Basin F. Measurements at the CMP boundary indicated a maximum average of $1.68 \mu\text{g}/\text{m}^3$ at AQ2 during Phase 1. An annual average ethylbenzene concentration of $1.38 \mu\text{g}/\text{m}^3$ was measured at perimeter Station AQ1 during Phase 4. This may have been influenced by metropolitan Denver air quality or other off-Arsenal sources. Basin F appeared to be a localized source of ethylbenzene during Phases 1 and 2. However, the 24-hour maximum level, $13.0 \mu\text{g}/\text{m}^3$, was less than 1 percent of the 24-hour guideline of $4350 \mu\text{g}/\text{m}^3$.

Toluene - A 24-hour maximum toluene concentration of $158 \mu\text{g}/\text{m}^3$ was measured at BF2 during Phase 1. Maximum 24-hour values decreased to less than $10 \mu\text{g}/\text{m}^3$ at other Basin F monitoring sites by the end of Phase 2. Outlying CMP monitoring stations showed a maximum short-term toluene level of $34.4 \mu\text{g}/\text{m}^3$ at AQ1 on the western RMA boundary and $27.6 \mu\text{g}/\text{m}^3$ at AQ4 on the eastern boundary during Phase 1. CMP values were $17 \mu\text{g}/\text{m}^3$ or less during Phases 3 and 4. The maximum 24-hour short-term measurement was 3 percent of the 24-hour guideline of $5600 \mu\text{g}/\text{m}^3$. The long-term maximum average toluene level, $23.6 \mu\text{g}/\text{m}^3$ at BF2, was 6 percent of the annual guideline of $400 \mu\text{g}/\text{m}^3$. During Phase 4, average toluene concentrations ranged from 3.49 to $11.3 \mu\text{g}/\text{m}^3$ at the CMP stations.

The higher toluene levels in the vicinity of Basin F indicated there was a source of this compound due to cleanup operations. However, higher short-term and average toluene levels at the RMA boundary stations also suggested other sources of toluene, most likely from metropolitan Denver traffic and industrial activities. Average levels of toluene were lower and more uniform during Phases 3 and 4 at all Basin F and CMP sites.

Other Comparisons - Tables 4.6-10 and 4.6-11 compare toxic guidelines with CMP, Basin F and IRA-F Program maximum short-term and longer-term concentrations for 22 VOC compounds. The last four columns also provide a comparison of highest RMA boundary site concentrations and the guidelines. At the boundaries, most of the measured analyte concentrations were less than 1 percent of the various guidelines. One analyte that was above 1 percent, benzene, does not appear to be entirely associated with remediation activities, but may result from both on-Arsenal and off-Arsenal activities. Carbon tetrachloride and chloroform were identified as concerns because of the very low annual levels established by state guidelines. Chloroform has been discussed previously. For carbon tetrachloride, the annual guideline (median value) is $0.67 \mu\text{g}/\text{m}^3$. The maximum average carbon tetrachloride level measured was $1.99 \mu\text{g}/\text{m}^3$ at RIFS2 during Phase 2 Stage 1. This is greater than 100 percent of the guideline; however, the fraction is reduced to only 2.4 percent if the TLV/420 value, $82 \mu\text{g}/\text{m}^3$, is used as a guideline.

The EPA conducted an air toxic study in the Denver area during the summer of 1987 and the winter of 1987-88. This study was discussed in the CMP FY89 Contamination Assessment Report and a comparison was made between maximum VOC concentrations measured in the Denver study and those measured at RMA (Stollar, 1990). An update of the results is provided in Table 4.6-12 (last column). All VOC concentrations in FY90 were considerably less than the maximum values reported in the Denver study, with the exception of o-xylene. This compound was nearly the same as maximum levels previously reported at RMA and still below the Denver study value. It is difficult to draw definite conclusions from these data because the quantification of the extreme values under any analytical method is less certain than mean values.

Table 4.6-12 Comparison of EPA Air Toxic Study and RMA Results for VOCs

Analyte	Maximum Concentration for Denver Study* ($\mu\text{g}/\text{m}^3$)	Maximum Concentration At RMA ($\mu\text{g}/\text{m}^3$) (Phases 1-3)	Maximum Concentration At RMA ($\mu\text{g}/\text{m}^3$) (Phase 4)
1,2-Dichloroethane	49	4	0.2
1,1,1-Trichloroethane	44	73	7.2
Carbon Tetrachloride	3	10	1.9
Trichloroethene	4	40	0.5
Tetrachloroethene	14	24	6.3
Benzene	83	44	7.5
Toluene	294	158	16.9
Ethylbenzene	22	13	5.3
o-Xylene	13	8	5.9
m- and p-Xylene (Total Xylenes)	252	50	9.5
Chlorobenzene	83	3	0.1

*Source: U.S. EPA. 1989. Report on the Air Toxics Monitoring Program for the Denver Metropolitan Area. Integrated Environmental Management Project. Report One, Data Summary. Region VIII, Denver, Colorado.

Where toxic guidelines vary significantly, perhaps a more meaningful evaluation would be a comparison of the RMA-measured VOC compounds with typical urban VOC levels. Table 4.6-13 compares the CMP VOC results for FY90 to published EPA studies for both the Denver metropolitan area as well as a summary of "air toxic" results from studies across the country. CMP concentrations were generally found to be less than the concentrations reported by the EPA urban airshed studies, as stated in the FY89 Report. While the average maximum levels of chloroform, benzene, and carbon tetrachloride, identified as concerns at the RMA boundaries, and other compounds identified as potential source emissions from Basin F, were equivalent to or below Denver and other urban sources levels, this is not to negate concern over these compounds or suggest that some potentially toxic air compounds may not have been emitted from various RMA sources and remedial activities. Analysis of results, again, suggests continued monitoring of these compounds with additional emphasis placed on identifying specific RMA local sources from new remediation activities, as well as regional emission sources. Concentrations of some compounds may be the result of previous Arsenal production activities; others are typical industrial and traffic related compounds and are released throughout the Denver urban metropolitan area. Several compounds were directly related to cleanup actions including emissions from vehicles and heavy equipment. Chloroform was identified in

Table 4.6-13 Ambient Volatile Organic Compounds (VOC) Concentrations from Various Studies

Target Name	1987 EPA NMOC Study Means $\mu\text{g}/\text{m}^3$	1988 EPA UATMP Mean $\mu\text{g}/\text{m}^3$	FY90 CMP* Basin F Mean $\mu\text{g}/\text{m}^3$	FY90 CMP* Basin A Mean $\mu\text{g}/\text{m}^3$	FY90 CMP* S. Plants Mean $\mu\text{g}/\text{m}^3$	FY90 CMP* Perimeter Mean $\mu\text{g}/\text{m}^3$
1,1,1-Trichloroethane	18.6	6.7	2.341	1.993	2.206	2.189
1,1,2-Trichloroethane	-	3.0	-	-	-	-
1,1-Dichloroethane	13.7	2.0	-	-	-	-
1,2-Dichloroethane	25.1	8.1	0.094	0.055	0.024	0.064
Benzene	6.5	5.2	1.618	1.604	1.464	2.228
Bicycloheptadiene	-	-	-	0.193	0.154	-
Carbon Tetrachloride	-	2.1	0.550	0.633	0.332	0.516
Chlorobenzene	7.4	3.0	-	-	0.026	-
Chloroform	-	30.8	0.457	1.728	0.290	0.132
Dicyclopentadiene	-	-	-	-	0.049	-
Dimethyl disulfide	-	-	-	-	-	-
Ethylbenzene	-	7.0	0.323	0.419	0.384	0.912
Methylene Chloride	78.4	18.1	7.558	7.201	5.068	4.516
Methylisobutyl Ketone	-	-	-	-	0.137	-
m-Xylene	59.1	18.7	-	-	-	-
N-Nitrosodimethylamine	-	-	-	-	-	-
o-Xylene (12DMB)	7.4	5.7	0.547	0.563	0.535	1.196
p-Xylene	59.1	18.9	-	-	-	-
Tetrachloroethylene	34.1	13.1	0.855	0.653	1.096	1.437
Toluene	32.0	16.4	6.187	6.062	8.274	6.928
Trans-1,2-Dichloroethylene	9.7	4.4	-	-	-	-
Trichloroethylene	20.8	10.4	0.097	0.147	0.076	0.091

Source: U.S. EPA, 1988. 1987 Nonmethane Organic Compound and Air Toxics Monitoring Program, Final Report, Vol. II, "Toxic Species." EPA-450/4-88-012. Research Triangle Park, North Carolina: U.S. EPA Office of Research and Development.
 * Data from both within and above the certified range are reported here.

Legend: NMOC = Nonmethane Organic Compound
 IEMP = Integrated Environmental Monitoring Program
 UATMP = Urban Air Toxics Monitoring Program

Basin F and the South Plants on several occasions. Other compounds monitored at RMA were randomly distributed and it appears that the source was from industrial activity and vehicle traffic outside of the Arsenal. Arsenal VOC measurements need to be evaluated quantitatively in terms of other urban sources. The CMP will continue to address this issue.

In general, compounds measured at RMA did not appear to present toxic health risks significantly different from the urban environment of metropolitan Denver. Organic compounds that were unique to Basin F decreased rapidly with distance from this source and were at lower levels at the RMA boundaries.

4.6.6 VOC NONTARGET ANALYTE RESULTS

Volatile organic compound samples from the CMP were analyzed not only for target VOCs compounds but also for any nontarget compounds that were observed. The target compound list was derived based on analyses of a variety of previous air monitoring and source characterization studies as well as the types of chemical processes, raw feed materials, and by-products that were associated with previous operations at RMA. The target list represents potential contaminants of concern that would be specific to RMA. Tentative identification and semi-quantification of nontarget compounds was performed in order to evaluate the significance of nontarget compounds and to update the target analyte list.

4.6.6.1 Laboratory Procedures

The laboratory analysis and data processing procedures for nontarget VOCs differed from target VOC procedures. Target VOCs were directly compared to responses and retention times from standards for that analyte on a gas chromatograph/mass spectrometer (GC/MS) system. Nontarget VOCs were tentatively identified by analyzing the total ion chromatogram for any peak that was greater than 10 percent of the internal standard area. The observed mass spectrum for that peak was compared to a library of spectra contained in the master spectral library, from the National Bureau of Standards/Wiley/Stirs Spectra, which contains approximately 72,000 compounds. A best fit match and a level of uncertainty was obtained. Semi-quantification could then be performed using an estimated response factor of one. Because the nontarget VOC results were not verified by use of an authentic standard, these results must be considered tentative identifications. The amounts which were calculated are estimates and must be used with caution.

4.6.6.2 Summary of Nontarget VOCs

The essential questions regarding observed nontarget compounds include: (1) what actual compounds or chemical types were detected, (2) how often did they occur, (3) at what site did they occur, (4) at what levels, and (5) what toxicity or significance is associated with these levels. Some of the nontarget compounds were grouped into categories based on similar chemical and toxicological characteristics. The group of freons include multichlorofluorinated ethane and methane hydrocarbons, which are commonly used as propellants or refrigerants. The toxicity of the compounds in each group was relatively uniform as judged by Threshold Limit Values (TLVs) established by the American Council of Government and Industrial Hygienists (ACGIH, 1986). For example, the TLVs for dichlorodifluoromethane, trichlorofluoromethane, and trichlorotrifluoroethane were all approximately 5 to 7.5 mg/m³.

Table 4.6-14 presents a summary listing of all nontarget compounds or compound groups that were detected from the CMP monitoring sites during the FY90 program. It includes the number of detections for each compound or compound group, and the maximum and minimum concentrations at each site. The total number of observed nontarget VOCs was 2,616. There were 1,401 detections of alkanes where the observed maximum concentration of 14 µg/m³ was detected at site AQ5. The alkanes represented over 53 percent of all observed nontarget detections. There were 489 detections of simple nonhalogenated aromatic hydrocarbons (benzenes) with the maximum concentration of approximately 14 µg/m³ observed at site AQ1. These aromatic hydrocarbons represented 19 percent of all observed nontarget VOCs. The next largest group of nontarget compounds was composed of oxygenated compounds, representing 12 percent of all nontarget detections. These groups are common components of urban airsheds and are reaction products of hydrocarbon emissions as part of the "smog" reactions process.

The Tenax trapping and desorbing procedure is known to produce interferences when the packing material comes in contact with ozone, NO_x, chlorine and temperatures higher than 200°C. The compounds observed from the reaction of Tenax with the above are benzaldehyde, acetophenone, phenol, and benzene. Precautions are taken during the sampling and handling process to minimize the exposure of the tubes to these situations. Benzene-type compounds and benzaldehyde were also uniformly detected at all sites. More samples were taken at AQ01, AQ02, AQ23, AQ26, AQ35 and AQ36 which consisted of several mobile sites in these sections.

Table 4.6-14 Summary of VOC Nontargets for FY90 (in $\mu\text{g}/\text{m}^3$)

Unknown ID	AQ1		# Hits	AQ2		# Hits	AQ3		# Hits	AQ4		# Hits
	Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.	
Acetate Ester			0			0	0.23	0.23	1			0
Aldehydes	9.17	0.14	11	0.41	0.18	2	9.17	0.05	14	9.17	0.14	10
Alkanes	13.76	0.05	243	0.45	0.05	19	9.17	0.05	198	9.17	0.03	154
Alkenes	2.75	0.05	6			0	0.92	0.05	8	1.38	0.02	7
Analytical Interference	0.93	0.09	6			0	0.93	0.05	11	0.92	0.05	12
Benzaldehyde	1.87	1.87	1			0	9.17	0.93	5	1.91	0.93	4
Benzenes	13.76	0.05	76	0.91	0.05	9	9.17	0.05	66	4.59	0.03	53
Chlorinated Hydrocarbons			0			0			0			0
Cyclohydrocarbons	0.92	0.41	2	0.09	0.09	1			0			0
Dichlorobenzene			0			0			0			0
Ethyl Acetate			0			0	3.67	0.24	2	0.18	0.18	1
Fatty Acids			0			0	0.14	0.14	1	0.09	0.09	2
Freons	9.17	0.05	6	0.45	0.14	2	0.92	0.14	4	0.99	0.46	4
Ketones	9.17	0.05	18	0.14	0.09	2	1.83	0.09	15	1.38	0.05	11
Naphthalene	1.83	0.05	4			0	0.28	0.09	4	0.09	0.03	3
Nitrogen-containing Compounds			0			0			0			0
Octafluorotoluene	1.84	1.84	1			0			0			0
Oxygenated Compounds	9.43	0.05	46	0.14	0.05	3	9.17	0.05	42	9.17	0.05	49
Phenols			0			0	0.41	0.14	2	0.23	0.05	2

Table 4.6-14 Summary of VOC Nontargets for FY90 (in $\mu\text{g}/\text{m}^3$) (continued)

Unknown ID	AQ5		AQ6		AQ8		AQ9	
	Max.	Min.	# Hits	Max.	Min.	# Hits	Max.	Min.
Acetate Ester	9.35	0.09	0			0	0.47	0.47
Aldehydes	14.02	0.04	9			0	3.77	0.05
Alkanes	1.87	0.14	215	1.39	0.05	21		
Alkenes			5			0		
Analytical Interference	1.40	0.14	6	0.09	0.05	2	0.47	0.24
Benzaldehyde	2.07	0.95	4			0	2.36	2.26
Benzenes	9.48	0.05	79	0.32	0.05	6	0.94	0.09
Chlorinated Hydrocarbons			0			0		
Cyclohydrocarbons	0.46	0.46	1			0		
Dichlorobenzene			0			0	0.93	0.93
Ethyl Acetate			0	0.05	0.05	1		
Fatty Acids			0			0		
Freons	0.94	0.05	7			0		
Ketones	1.40	0.05	20	0.46	0.46	2	1.42	1.42
Naphthalene	0.28	0.05	5			0		
Nitrogen-containing Compounds			0			0		
Octafluorotoluene			0			0		
Oxygenated Compounds	2.84	0.05	39	4.63	0.09	6	2.80	0.19
Phenols			0			0	2.36	0.09
						8		
						0		

Table 4.6-14 Summary of VOC Nontargets for FY90 (in $\mu\text{g}/\text{m}^3$) (continued)

Unknown ID	AQ10			AQ01			AQ02			AQ23		
	Max.	Min.	# Hits	Max.	Min.	# Hits	Max.	Min.	# Hits	Max.	Min.	# Hits
Acetate Ester			0			0			0			0
Aldehydes			0	0.28	0.19	6			0			0
Alkanes	2.80	0.05	41	1.86	0.05	199	1.88	0.05	25	3.76	0.05	43
Alkenes			0	0.28	0.05	12			0			0
Analytical Interference	0.19	0.09	3	0.47	0.07	8	0.19	0.19	2	1.88	0.09	2
Benzaldehyde	2.31	2.31	1			0			0	0.93	0.93	1
Benzenes	0.46	0.05	14	2.33	0.05	82	2.82	0.05	12	1.88	0.05	14
Chlorinated Hydrocarbons			0			0			0			0
Cyclohydrocarbons			0			0			0			0
Dichlorobenzene			0	0.33	0.09	4	0.47	0.47	1			0
Ethyl Acetate	0.19	0.19	1			0			0			0
Fatty Acids			0			0			0			0
Freons			0	1.49	0.18	7			0	0.93	0.93	1
Ketones	0.93	0.23	4	0.47	0.05	20	0.47	0.47	2	0.94	0.09	3
Naphthalene	0.05	0.05	1	0.23	0.09	5			0	0.47	0.47	1
Nitrogen-containing Compounds			0			0			0			0
Octafluorotoluene			0			0			0			0
Oxygenated Compounds	9.35	-0.05	18	1.85	0.05	31	0.47	0.09	5	4.69	0.05	14
Phenols			0	0.23	0.09	4			0			0

Table 4.6-14 Summary of VOC Nontargets for FY90 (in $\mu\text{g}/\text{m}^3$) (continued)

Unknown ID	AQ26		AQ35		AQ36		TOTAL	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Acetate Ester							0.23	0.00
Aldehydes	1.88	0.14			1.39	0.47	9.35	0.00
Alkanes	4.23	0.05	0.50	0.05	1.42	0.05	14.02	0.04
Alkenes							2.75	0.00
Analytical Interference	1.86	0.05	0.10	0.05	0.28	0.09	1.88	0.05
Benzaldehyde	1.40	0.23	1.98	1.98	2.31	2.31	9.17	0.00
Benzenes	4.65	0.05	0.95	0.05	0.93	0.09	13.76	0.05
Chlorinated Hydrocarbons					0.37	0.37	0.37	0.00
Cyclohydrocarbons							0.92	0.00
Dichlorobenzene			0.14	0.14	0.24	0.24	0.93	0.00
Ethyl Acetate	0.09	0.09					3.67	0.00
Fatty Acids							0.14	0.00
Freons	0.94	0.47	0.99	0.48			9.35	0.00
Ketones	0.94	0.09	0.30	0.14	0.47	0.46	9.17	0.00
Naphthalene							1.83	0.00
Nitrogen-containing Compounds					2.36	2.36	2.36	0.00
Octafluorotoluene							1.84	0.00
Oxygenated Compounds	2.33	0.05	0.50	0.05	0.94	0.05	9.43	0.05
Phenols							0.41	0.00

Typical urban airsheds have been known to contain many VOC compounds, with both industrial and vehicular sources being major emitters. The emissions include both aliphatic and aromatic hydrocarbons, and the freon-type of halogenated aliphatics. These VOCs can then react in the photochemical smog process to form other groups of compounds, most notably aldehydes and ketones. These compound types represented the majority of the nontarget compounds observed; therefore, most of the nontarget compounds appeared to be related to the influx of urban VOCs onto RMA.

The summary of VOC blank nontargets for FY90 is found in Table 4.6-15. The total number of observed nontarget detections in the VOC blanks was 32. Thirteen detections were found at site AQ4 and 12 detections at site AQ3. All detections were at low levels ranging from 0.01 to 0.20 μg . The origin of the contamination can be traced to three possibilities, including crew handling, sample exposure during shipping and storage, and breakdown products from the adsorbing media.

4.7 SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs) AND ORGANOCHLORINE PESTICIDES (OCPs)

4.7.1 MONITORING, ANALYSIS AND REPORTING STRATEGIES

Both the SVOC and OCP monitoring programs, which provide measurements of pesticide levels at the Arsenal interior and perimeter sites, are contained in this section. As prescribed in the CMP Technical Plan, the F-7 GC/MS method was initially used for analyses of SVOC. During the FY88 Basin F remedial period, the H-7 GC/ECD method was also used to confirm low levels of SVOC pesticides. The H-7 method is about 100 times more sensitive to pesticides than the F-7 method, and proved to be more appropriate for monitoring SVOC pesticide levels at RMA. In FY88, there were only minimal detections of SVOC under the F-7 method, and in FY89 and FY90, there were no detections under this method. The more sensitive H-7 method identified pesticides for both of these periods for the Basin F and IRA-F monitoring programs (H-7 was not used for CMP during FY89). In FY90, methods CM02 and CM03, more sensitive versions of F-7, were employed to analyze pesticides during CMP SVOC high event episodes.

The OCP program, designed to measure pesticide concentrations routinely (every 12th day) at three Arsenal perimeter sites, AQ1, AQ3, and AQ5, also used the H-7 GC/ECD analytical method. Consequently, the combined results of SVOCs and OCPs are discussed in this section to provide a more complete evaluation of the distribution of pesticides across the Arsenal.

Table 4.6-15 Summary of VOC Blank Nontargets for FY90

Maximum and Minimum Data in μg

Nontarget	Max.	AQ1 Min.	# Hits	Max.	AQ3 Min.	# Hits	Max.	AQ4 Min.	# Hits
Aldehydes				0.01	0.01	1	0.02	0.02	1
Alkanes	0.02	0.02	1	0.06	0.01	2	0.06	0.03	2
Analytical									
Interference	0.02	0.01	4	0.10	0.03	3	0.04	0.01	4
Benzaldehyde				0.02	0.01	2	0.02	0.02	1
Freons	0.01	0.01	1	0.20	0.04	2	0.04	0.04	1
Ketones				0.02	0.02	1			
Oxygenated Compounds				0.03	0.03	1	0.02	0.01	4

Nontarget	Max.	AQ5 Min.	# Hits	TOTAL		
				Max.	Min.	# Hits
Aldehydes				0.02	0.01	2
Alkanes				0.06	0.01	5
Analytical						
Interference				0.10	0.01	11
Benzaldehyde				0.02	0.01	3
Freons	0.05	0.05	1	0.20	0.01	5
Ketones				0.02	0.02	1
Oxygenated Compounds				0.03	0.01	5

The CMP Technical Plan called for SVOC seasonal monitoring at four RMA perimeter sites during the spring, summer, fall and winter periods, and six high event sampling episodes to be conducted at four fixed perimeter sites or at other fixed or mobile sites as appropriate. Because there was intense remedial activity at Basin F during FY88 and FY89, some emphasis was placed on sampling in its immediate vicinity, similar to the emphasis for monitoring VOCs. However, RMA perimeter sites were also sampled under the high event SVOC and the OCP programs in order to establish pesticide levels around the Arsenal boundaries. During FY90, high event SVOC monitoring was conducted at Basin F, the South Plants, the South Plants subdrain area, Basin A, and Basin A Neck.

For the most part, all CMP high event SVOC monitoring met the specified meteorological criteria of 75°F or greater. Two wind criteria scenarios were established for the SVOC high event sampling as shown previously in Table 3.2-3, one for light winds similar to VOC sampling, and a second for winds in excess of 10 mph in order to capture SVOCs adhering to windborne particles. The monitoring program contained samples of both situations. Also, as in the case of VOCs, the CMP FY90 SVOC monitoring period was extended to 24 hours to attempt to capture SVOC trapped under early morning or late afternoon inversion conditions.

4.7.2 CMP FY90 SEMI-VOLATILE ORGANIC COMPOUNDS MONITORING RESULTS

Seasonal and high event semi-volatile organic compounds were monitored during the FY90 program at the times and locations given in Table 4.7-1. A complete listing and summary of SVOCs is provided in Appendix F.

OCP compounds were monitored under the CMP FY90 program routinely (every 12 days) at three RMA perimeter sites as shown in Table 4.7-2.

Table 4.7-1 Synopsis of FY90 Semi-Volatile Organic Compounds (SVOC) Monitoring

Date	Period	Site Locations
January 12, 1990*	1130 - 1130	Mobile N, Mobile S
May 21, 1990*	1130 - 1130	AQ1, AQ2, AQ3, AQ5E, AQ5F
July 18, 1990	1200 - 1200	FC2, FC2C, FC3, FC5, Mobile SE
August 2, 1990	1200 - 1200	FC2, FC2C, FC3, FC4, FC5
August 7, 1990	1000 - 1000	Mobile 1, Mobile 2, Mobile 3, Mobile 4 South Plants)
August 27, 1990	0900 - 0900	AQ8, AQ9, Mobile E, Mobile EC, Mobile W (Sec. 36)
August 29, 1990	1000 - 1000	AQ10, AQ10C, Mobile N (Sec. 26), Mobile S, Mobile W (Sec. 35)
September 11, 1990	0800 - 0800	AQ6, AQ10, AQ10C, Mobile E (Sec. 1), Mobile W (Sec. 2)

* Seasonal monitoring; all others were high event monitoring cases.

Table 4.7-2 Synopsis of FY90 Monitoring for Organochlorine Pesticides (OCP)

Station	Number of Samples	Percent Recovery
AQ1	28	93
AQ3	28	93
AQ5E	25	83
AQ5F*	12	100

* Collocated station

As noted previously, the CMP monitoring results for FY90 indicated no detections of SVOC employing the GC/MS F-7 method. Table 4.7-3 shows FY90 results using the CM02 and CM03 methods during high event monitoring periods. The CM02 method was used for SVOC analysis by the MRI laboratory, while the CM03 method was used for SVOC analysis by the ESE laboratory.

Table 4.7-3 Summary of Semi-Volatile Organic Compounds Concentrations for FY90 Pesticide Method (in $\mu\text{g}/\text{m}^3$)

Site	Aldrin	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE1	PPDDT
AVERAGE VALUES							
AQ6	*	0.0012	0.0006	*	*	*	*
AQ8	0.0005	0.0021	0.0020	0.0004	*	*	*
AQ9	*	*	*	*	*	*	*
AQ10	*	0.0023	0.0060	0.0006	*	*	*
AQ01	0.0020	0.0034	0.0055	0.0008	*	*	*
AQ02	*	0.0015	0.0014	*	*	*	*
AQ23	*	0.0008	0.0016	0.0005	*	*	*
AQ26	0.0002	0.0015	0.0038	0.0007	*	*	*
AQ35	*	0.0015	0.0010	*	*	*	*
AQ36	0.0012	0.0027	0.0039	0.0004	*	*	*
24-HOUR MAXIMUM VALUES							
AQ6	*	0.0012	0.0006	*	*	*	*
AQ8	0.0005	0.0021	0.0020	0.0004	*	*	*
AQ9	*	*	*	*	*	*	*
AQ10	*	0.0034	0.0096	0.0009	*	*	*
AQ01	0.0029	0.0055	0.0074	0.0015	*	*	*
AQ02	*	0.0015	0.0014	*	*	*	*
AQ23	*	0.0026	0.0052	0.0009	*	*	*
AQ26	0.0002	0.0033	0.0084	0.0010	*	*	*
AQ35	*	0.0016	0.0012	*	*	*	*
AQ36	0.0017	0.0029	0.0055	0.0006	*	*	*

* All values below CRL

- 1 PPDDE = Dichlorodiphenylethane
 2 PPDDT = Dichlorodiphenyltrichloroethane

There are only slight differences in detection limits between these methods. Table 4.7-4 shows OCP results for the three RMA perimeter sites during FY90 using the H-7 analytical method.

During FY90, low levels of aldrin, chlordane, dieldrin and endrin were detected at several interior Arsenal locations. Average and maximum SVOC levels actually analyzed by the OCP method (Table 4.7-3) at the Arsenal interior were slightly higher than values measured at the perimeter under the OCP program (Table 4.7-4). One explanation for this is that all interior measurements were obtained on high event days, while the perimeter sites were measured routinely throughout the year. Nevertheless, the data suggest that there are potential low level sources of pesticides at Basin F, the South Plants, and the Basin A area. Specific examples of SVOC FY90 high event monitoring episodes are discussed below.

4.7.2.1 August 2, 1990

SVOCs were monitored under this CMP high event scenario at four mobile stations surrounding the Basin F waste pile and remediated Basin area. Figure 4.7-1 shows site locations and sampling results for selected compounds, along with a wind rose for the monitoring period from 1300 MST on August 2 to 1300 MST on August 3, 1990. The maximum temperature during this period was 77°F with primarily south-southwesterly winds. Wind speeds ranged from 5 mph to a maximum of 21 mph during the late afternoon on August 2. Atmospheric stability was mainly in the neutral category as a result of moderate wind speeds, but a late evening inversion developed as wind speeds decreased.

Assuming Basin F as a potential SVOC source, the dispersion pattern in Figure 4.7-1 shows the greatest impacts to the north and northeast of the Basin F area. The highest dieldrin level measured was 0.0084 $\mu\text{g}/\text{m}^3$ at FC2 northeast of the Basin and downwind from the source. Station FC3 upwind from Basin F measured 0.0034 $\mu\text{g}/\text{m}^3$. This slight difference between the upwind and downwind monitors suggests a possible source of dieldrin emissions at the Basin F area. Similarly, endrin levels were slightly higher at downwind stations FC2 (0.0010 $\mu\text{g}/\text{m}^3$) and FC5 (0.0009 $\mu\text{g}/\text{m}^3$) than at FC3 (0.0006 $\mu\text{g}/\text{m}^3$), upwind from the Basin. Chlordane levels were evenly distributed at the four Basin F sites. As noted in past reports, Basin F does not appear to be a chlordane source. On this sampling day, aldrin, isodrin, PPDDE, and PPDDT were not detected at any of the Basin F sites. Even though maximum levels of dieldrin and endrin were considerably below concentrations measured during the Basin F remediation activities, the Basin F area may still be a low level source of these compounds.

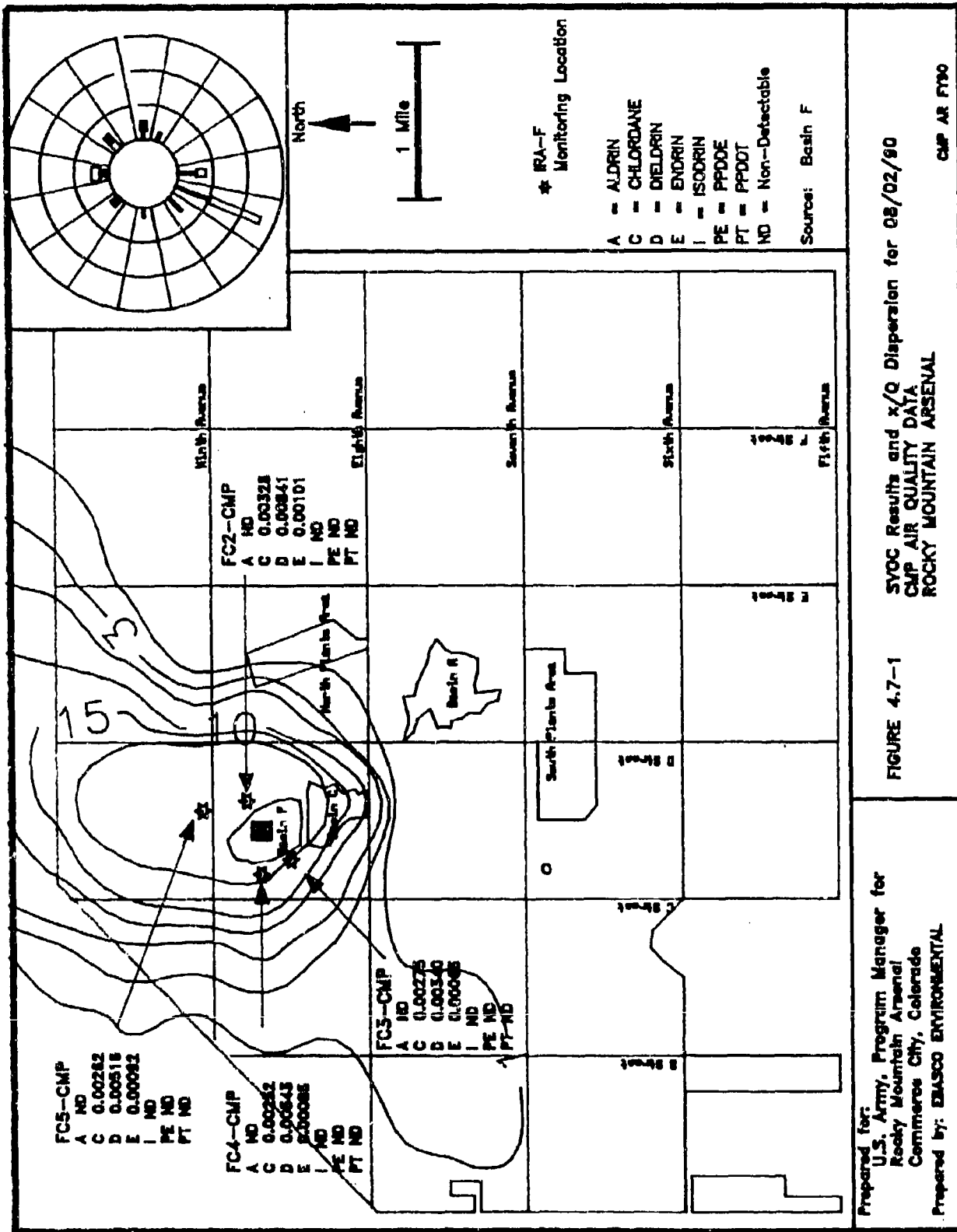
Table 4.7-4 Summary of CMP Organochlorine Pesticides Concentrations for FY90 (in $\mu\text{g}/\text{m}^3$)

Site	Aldrin	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE ¹	PPDDT ²
AVERAGE VALUES							
AQ1	0.0002	0.0003	0.0002	*	0.0002	*	*
AQ3	0.0003	0.0005	0.0008	0.0002	*	*	*
AQ5	0.0002	0.0003	0.0003	*	*	*	*
24-HOUR MAXIMUM VALUES							
AQ1	0.0004	0.0015	0.0014	*	0.0009	*	*
AQ3	0.0014	0.0029	0.0047	0.0004	*	*	*
AQ5	0.0002	0.0012	0.0015	*	*	*	*
MINIMUM VALUES							
AQ1	0.0001	0.0001	0.0001	*	0.0001	*	*
AQ3	0.0002	0.0001	0.0002	0.0002	*	*	*
AQ5	0.0001	0.0001	0.0001	*	*	*	*

* All values below CRL

1 PPDDE = Dichlorodiphenylethane

2 PPDDT = Dichlorodiphenyltrichloroethane



4.7.2.2 August 7, 1990

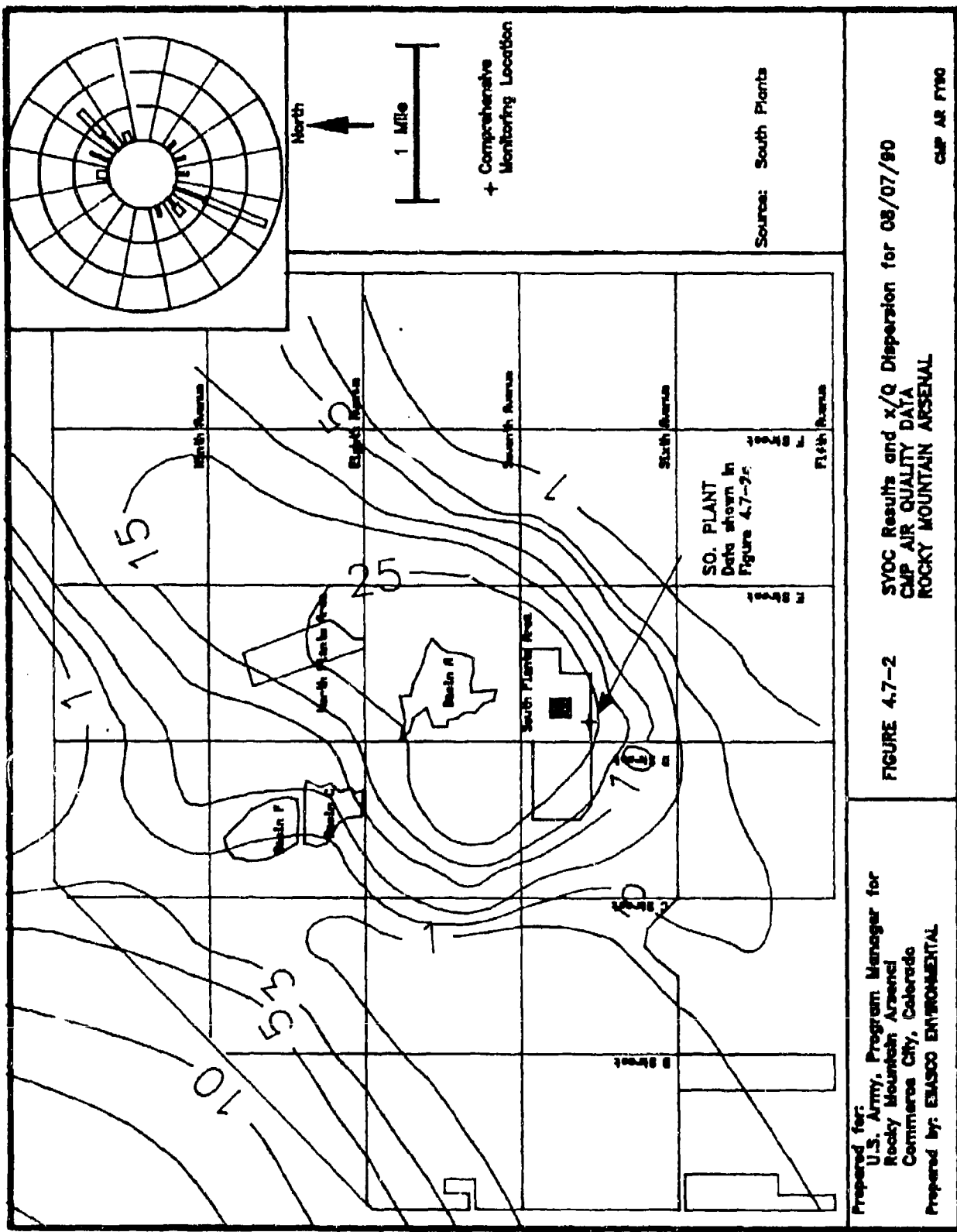
SVOCs were monitored under this CMP high event scenario at four mobile stations surrounding the South Plants area. Figures 4.7-2 shows the X/Q dispersion pattern and wind rose, and Figure 4.7-2a shows site locations and sampling results for selected compounds for the monitoring period. The maximum temperature on this day was 87°F. Winds were primarily from the south-southwest, although there was a northeasterly component during the mid-afternoon. Wind speeds were light on this day, ranging from 3 to 11 mph. Atmospheric stability was typical of a summer day; unstable during the midday period and stable to neutral during the evening, depending on wind speed.

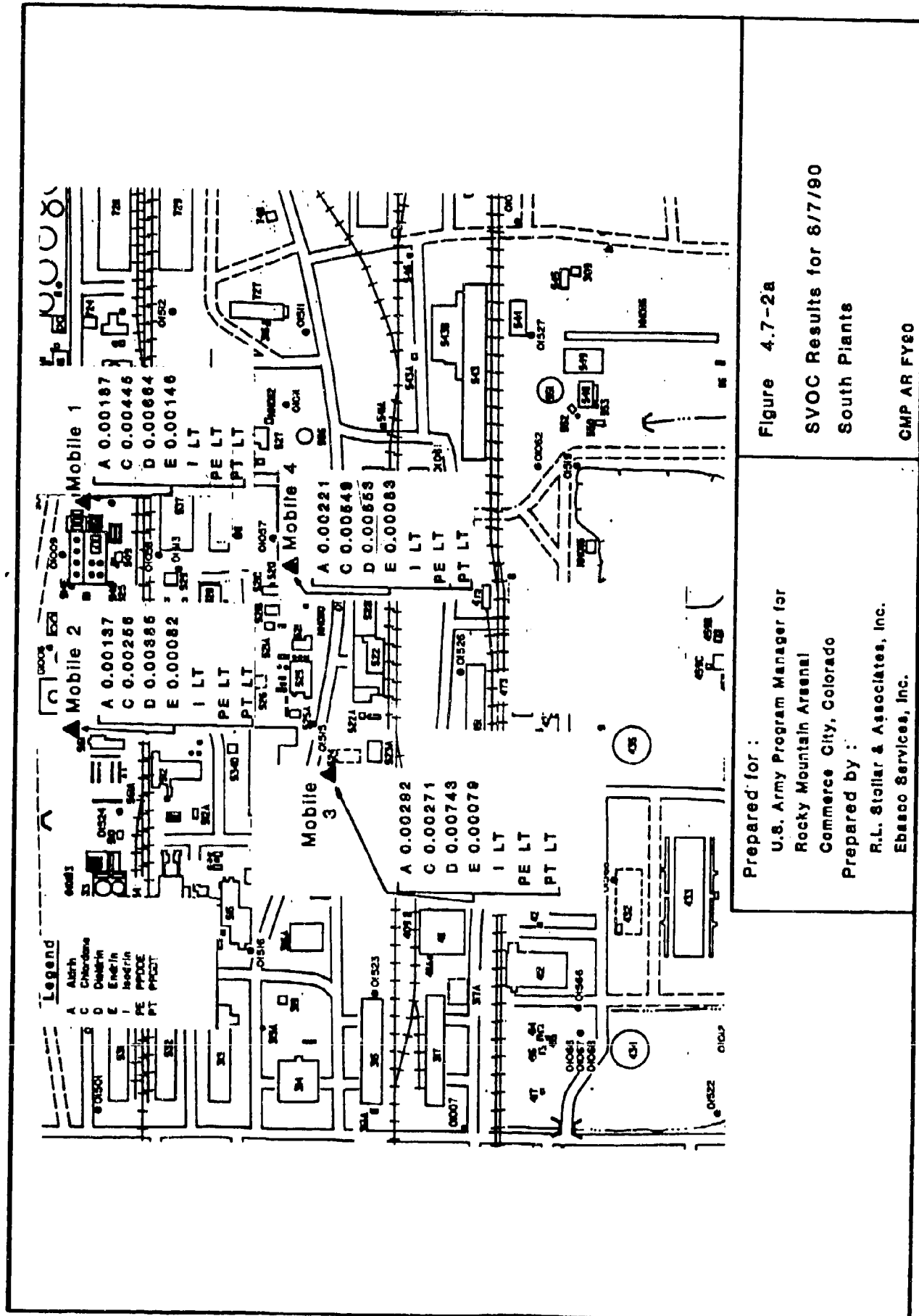
Assuming that the South Plants area was a potential SVOC source, the dispersion pattern indicates that greatest impacts were along the plume path to the northeast and southwest of the South Plants. The highest aldrin level of $0.0029 \mu\text{g}/\text{m}^3$ and dieldrin level of $0.0074 \mu\text{g}/\text{m}^3$ was measured at Mobile 3 to the southwest, while the highest endrin level of $0.0015 \mu\text{g}/\text{m}^3$ was measured to the northeast at Mobile 1. Chlordane was measured at its highest level, $0.0055 \mu\text{g}/\text{m}^3$, at Mobile 4 to the southeast of the South Plants. Isodrin, PPDE, and PPDDT were not detected on this sampling day. Although pesticides were measured along the plume path, it is difficult to determine if the South Plants was a source of these compounds. Concentrations were low, there were no consistent patterns for each parameter, and similar values were measured upwind as well as downwind. Endrin and dieldrin, previously identified as potential emissions from Basin F, could have drifted into the South Plants area.

4.7.2.3 August 29, 1990

SVOCs were monitored under this CMP high event scenario at four mobile stations surrounding the Basin A Neck excavation activities. Figure 4.7-3 shows site locations and sampling results for selected compounds along with a wind rose for the monitoring period. The maximum temperature on this day was 93°F. Winds were primarily from the south-southwest with a variable easterly component during the midday period. Wind speeds were light, ranging from 4 to 10 mph. Atmospheric stability was again typical of summer, with unstable air during the warm midday period and stable conditions at night under a weak inversion.

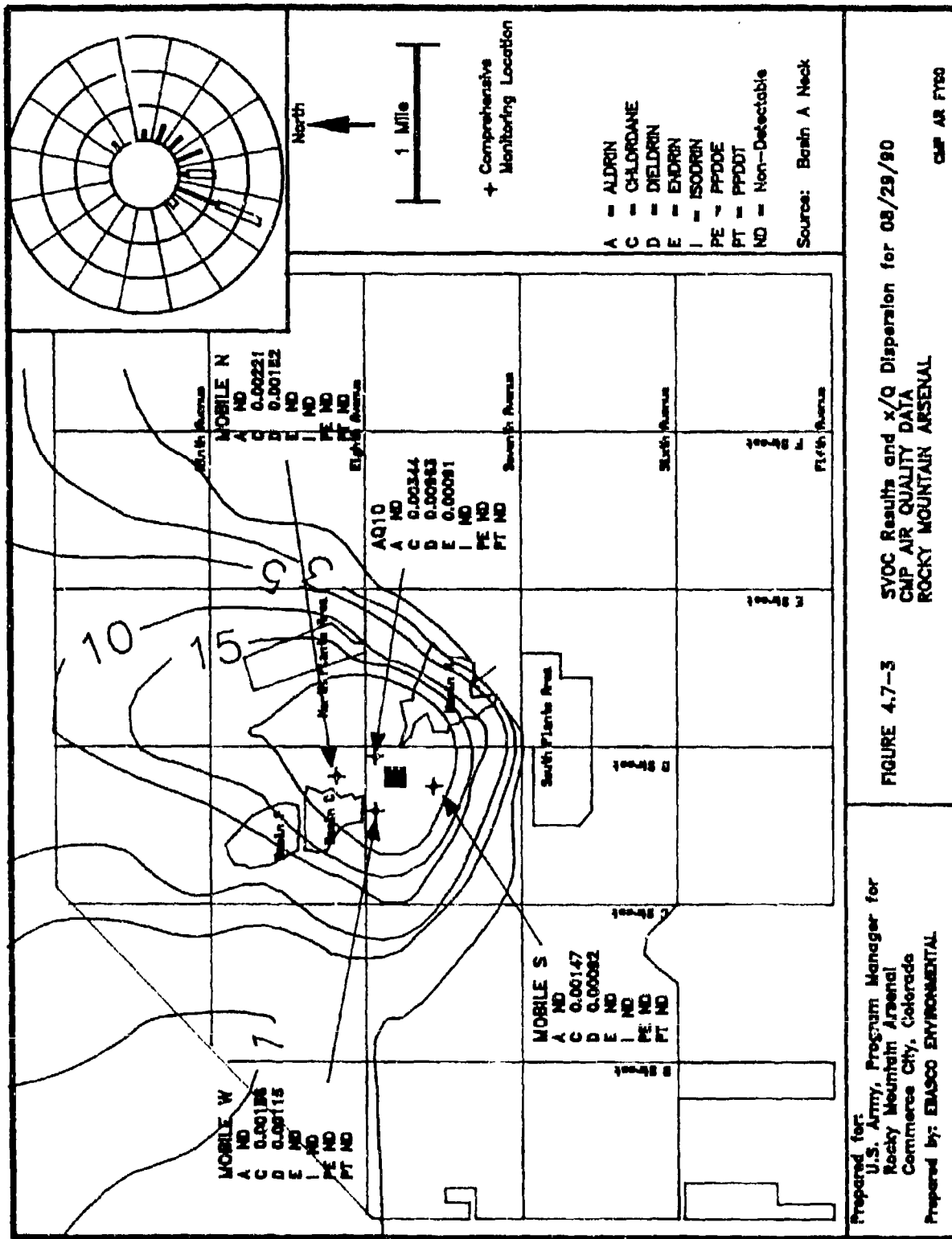
Assuming the Basin A Neck area to be a source of SVOCs, the dispersion pattern in Figure 4.7-3 indicates the impacts to be primarily north and northeast of the Neck area. The highest dieldrin level of $0.0096 \mu\text{g}/\text{m}^3$ was measured at AQ10 to the east of remediation activities. A chlordane





Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.



concentration of 0.0034 $\mu\text{g}/\text{m}^3$ was also highest at AQ10. Endrin levels of 0.0009 $\mu\text{g}/\text{m}^3$ were reported at AQ10. The relatively higher level of dieldrin could have resulted from Arsenal emissions or other possible off-Arsenal sources of SVOC emissions drifting into the area. These pesticide levels were considerably lower than levels measured during FY88 remediation activities.

It is important to point out that high event concentrations in FY90 were approximately two orders of magnitude lower for dieldrin and endrin than levels measured during Basin F remediation activities. Other pesticides such as isodrin, PPDDT, and parathion were detected during Basin F cleanup, but were not detected during the CMP FY90 high event program. There were, however, extremely low levels measured at the perimeter sites under the more sensitive H-7 analytical method. Comparative values will be discussed further in the next section, which provides a post-remedial evaluation.

4.7.3 BASIN F SVOC IMPACTS

4.7.3.1 CMP Data

As previously discussed, in order to fully evaluate remedial impacts from the Basin F cleanup operations, it is necessary to consider all CMP, Basin F Remedial Monitoring Program, and IRA-F SVOC data for the entire remedial and post-remedial periods. CMP FY90 SVOC data results were discussed in the previous section. Table 4.7-5 incorporates CMP FY88 through FY90 data and stratifies results for each monitoring station for the Phase 1 remediation period and the Phase 4 post-remedial period. The BF1 through BF4 sites for Phase 1 and the AQ23 and AQ26 sites for Phase 4 are at roughly comparable locations, near the edge of Basin F. High event SVOC monitoring was not conducted during Phase 2 (winter of FY89), and SVOCs were not detected during Phase 3 (summer of FY89); however, only the less sensitive F-7 analytical method was employed. This indirectly substantiates that levels were low during this post-remedial period. Nevertheless, the data for Phases 1 and 4 provide an excellent comparison between SVOCs measured under intense remediation activities and SVOCs measured during the most recent FY90 post-remedial period.

As discussed previously, dieldrin and endrin levels were approximately two orders of magnitude lower during the post-remedial period. Isodrin, PPDE, PPDDT, and parathion were detected during the Phase 1 remediation period, but were not measured during the FY90 post-remedial high event monitoring periods. Chlordane, which was measured at approximately equal levels during Phases 1 and 4, did not appear to be from a Basin F source during remediation. The substantial decreases in post-remedial pesticide measurements under the CMP are shown graphically in Figure 4.7-4.

Table 4.7-5 Summary of CMP Semi-Volatile Organic Compounds (SVOC) Concentrations by Phase (in $\mu\text{g}/\text{m}^3$)

	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE	PPDDT	Atrazine	Malathion	Parathion	Supona
AVERAGE VALUES										
PHASE 1										
AQ1	0.0011	0.0036	0.0013	0.0006	0.006	0.0014	*	*	*	*
AQ2	*	*	*	*	*	*	*	*	*	*
AQ3	0.0010	0.0060	0.0014	*	*	0.0008	*	*	*	*
AQ4	*	*	*	*	*	*	*	*	*	*
AQ5	0.0011	0.0021	0.0014	*	*	0.0023	*	*	*	*
AQ6	*	*	0.0040	*	*	*	*	*	*	*
AQ8	*	*	*	*	0.0390	*	*	*	*	*
AQ9	*	*	*	*	0.0198	*	*	*	*	*
CMP/BF1	*	0.2245	0.1208	0.0363	*	0.0069	*	*	*	*
CMP/BF2	*	0.3971	0.1343	0.1122	*	0.0350	*	0.1311	*	*
CMP/BF3	*	0.0423	0.0718	0.0054	*	*	*	*	*	*
CMP/BF4	0.0036	0.0584	0.0160	0.0040	*	0.0022	*	*	*	*
PHASE 4 (Pesticide Method)										
AQ6	0.0012	0.0006	*	*	*	*	*	*	*	*
AQ8	0.0021	0.0020	0.0004	*	*	*	*	*	*	*
AQ9	0.0024	*	*	*	*	*	*	*	*	*
AQ10	0.0023	0.0060	0.0006	*	*	*	*	*	*	*
AQ01	0.0034	0.0055	0.0008	*	*	*	*	*	*	*
AQ02	0.0015	0.0014	*	*	*	*	*	*	*	*
AQ23	0.0008	0.0016	0.0005	*	*	*	*	*	*	*
AQ26	0.0017	0.0038	0.0007	*	*	*	*	*	*	*
AQ35	0.0015	0.0010	*	*	*	*	*	*	*	*
AQ36	0.0027	0.0039	0.0004	*	*	*	*	*	*	*

* All values below CRL

LEGEND: PPDDE Dichlorodiphenylethane
PPDDT Dichlorodiphenyltrichloroethane

Table 4.7-5 Summary of CMP Semi-Volatile Organic Compounds (SVOC) Concentrations by Phase (in $\mu\text{g}/\text{m}^3$) (continued)

	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE	PPDDT	Atrazine	Malathion	Parathion	Supona
24-HOUR MAXIMUM VALUES										
PHASE 1										
AQ1	0.0023	0.0060	0.0028	0.0008	0.0008	0.0034	*	*	*	*
AQ2	*	*	*	*	*	*	*	*	*	*
AQ3	0.0024	0.0217	0.0027	*	*	0.0010	*	*	*	*
AQ4	*	*	*	*	*	*	*	*	*	*
AQ5	0.0028	0.0044	0.0032	*	*	0.0067	*	*	*	*
AQ6	*	*	0.0040	*	*	*	*	*	*	*
AQ8	*	*	*	*	0.0390	*	*	*	*	*
AQ9	*	*	*	*	0.0387	*	*	*	*	*
CMP/BF1	*	0.2245	0.1208	0.0363	*	0.0069	*	*	*	*
CMP/BF2	*	0.7210	0.2371	0.2525	*	0.0385	*	0.2099	*	*
CMP/BF3	*	0.0423	0.0718	0.0054	*	*	*	*	*	*
CMP/BF4	0.0036	0.0584	0.0160	0.0040	*	0.0022	*	*	*	*
PHASE 4 (Pesticide Method)										
AQ6	0.0012	0.0006	*	*	*	*	*	*	*	*
AQ8	0.0021	0.0020	0.0004	*	*	*	*	*	*	*
AQ9	0.0024	*	*	*	*	*	*	*	*	*
AQ10	0.0034	0.0096	0.0009	*	*	*	*	*	*	*
AQ01	0.0055	0.0074	0.0015	*	*	*	*	*	*	*
AQ02	0.0015	0.0014	*	*	*	*	*	*	*	*
AQ23	0.0026	0.0052	0.0009	*	*	*	*	*	*	*
AQ26	0.0033	0.0084	0.0010	*	*	*	*	*	*	*
AQ35	0.0016	0.0012	*	*	*	*	*	*	*	*
AQ36	0.0029	0.0055	0.0006	*	*	*	*	*	*	*

* All values below CRL

LEGEND: PPDDE Dichlorodiphenylethane
PPDDT Dichlorodiphenyltrichloroethane

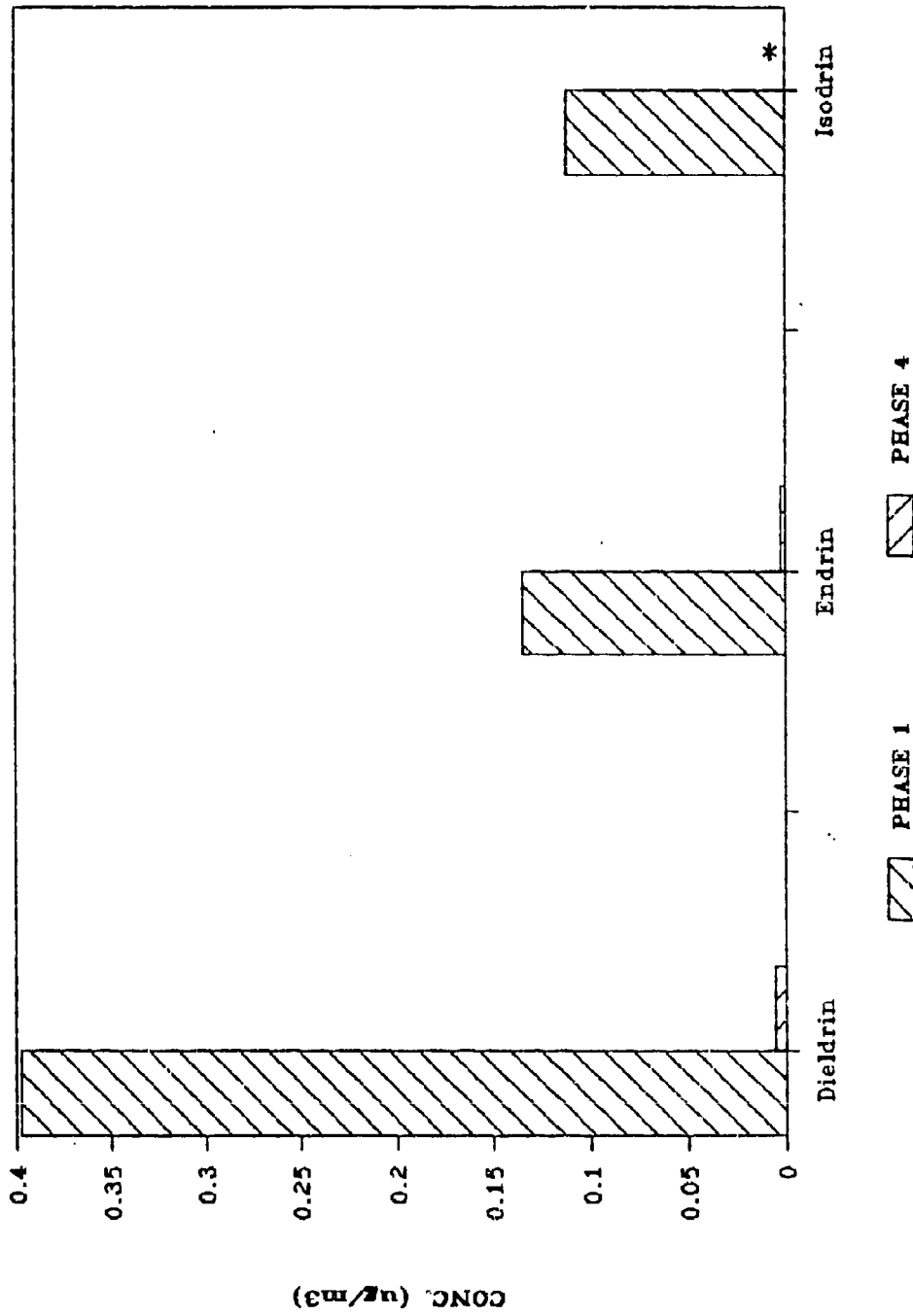


Figure 4.7-4
SVOC Results at CMP/BF2
for Phases 1 and 4

CMP AR FY90

Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

* Not detected

Comparative levels of dieldrin, endrin, and isodrin at station BF2 downwind from the prevailing wind flow across Basin F indicated highest concentrations of SVOCs during the remediation period.

Table 4.7-6 provides a comparison of OCPs at three Arsenal perimeter sites measured during each of the remediation Phases. Pesticide concentrations were considerably lower at the RMA perimeter than at the Basin F sites during Phase 1, reflecting a significant decrease of impacts with distance from the source. AQ3, the closest perimeter site to the Basin, reported the highest average concentrations of aldrin, dieldrin, endrin, and isodrin, which were previously identified as pesticides with potential Basin F sources. After remediation, average levels of these compounds were reduced and were comparable to the other perimeter sites. Maximum 24-hour levels of these compounds, however were elevated during Phase 4. The highest concentrations were observed on one particular sampling day, July 10, 1990, when CMP field technicians noticed spraying of the herbicide 24D by RMA personnel. On this day, the first observation of chlordane ($0.0006 \mu\text{g}/\text{m}^3$) and the only observation of endrin ($0.0004 \mu\text{g}/\text{m}^3$) for FY90 was recorded at AQ3. The highest concentrations of aldrin ($0.0011 \mu\text{g}/\text{m}^3$) and dieldrin ($0.0047 \mu\text{g}/\text{m}^3$) measured since Phase 1 also occurred on July 10 at site AQ3. OCP values occasionally reached higher levels at the AQ3 perimeter site than at interior Arsenal locations. In addition, there may have been off-Arsenal sources of OCPs from metropolitan Denver impacting RMA monitoring sites, as indicated by concentrations measured at other perimeter sites.

The emphasis in the SVOC sampling program is to provide a broad pattern of baseline air quality conditions at Arsenal remediation locations, interior locations, and perimeter sites. Because of the more intensive monitoring efforts under the Basin F Remedial Monitoring and IRA-F Program, the CMP concentrates its efforts on confirming and validating data collected from the other programs. The more detailed results of Basin F post-remedial monitoring for SVOCs is provided in the following section.

4.7.3.2 Basin F Data

Table 4.7-7 shows average and 24-hour maximum SVOC values for the Basin F Remedial Monitoring Program and for the IRA-F Monitoring Program for Phase 1 through Phase 4 of the remediation activities. All Phase 1 data and Phase 2 data (Stage 1 and Stage 2) were obtained from the Basin F Remediation Monitoring Program and cover the period from March 22, 1988, to May 5, 1989. The Phase 3 and Phase 4 data were obtained from the IRA-F Monitoring Program and cover a period from May 6, 1989, to September 30, 1990. Sequential data for the IRA-F SVOC and OCP programs are provided in Appendices P and Q.

Table 4.7-6 Summary of CMP Organochlorine Pesticides (OCP) by Phase (in $\mu\text{g}/\text{m}^3$)

Site	Aldrin	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE ¹	PPDDT ²
AVERAGE VALUES							
PHASE 1							
AQ1	0.0010	0.0003	0.0010	0.0006	0.0003	0.0005	0.0007
AQ3	0.0053	0.0003	0.0022	0.0013	0.0005	*	0.0004
AQ5	0.0013	0.0003	0.0013	0.0009	0.0003	0.0004	0.0006
PHASE 2							
AQ1	*	0.0003	0.0004	0.0004	*	*	0.0003
AQ3	*	0.0003	0.0004	0.0003	*	*	0.0003
AQ5	*	0.0003	0.0003	*	*	*	*
PHASE 3							
AQ1	*	0.0003	0.0004	*	0.0003	*	0.0003
AQ3	*	0.0004	0.0008	*	*	*	0.0004
AQ5	*	0.0003	0.0005	*	*	*	0.0004
PHASE 4							
AQ1	0.0002	0.0003	0.0002	*	0.0002	*	*
AQ3	0.0003	0.0005	0.0008	0.0002	*	*	*
AQ5	0.0002	0.0003	0.0003	*	*	*	*
24-HOUR MAXIMUM VALUES							
PHASE 1							
AQ1	0.0066	0.0005	0.0062	0.0026	0.0005	0.0058	0.0047
AQ3	0.0290	0.0005	0.0061	0.0041	0.0024	*	0.0012
AQ5	0.0095	0.0008	0.0074	0.0046	0.0008	0.0023	0.0050
PHASE 2							
AQ1	*	0.0003	0.0014	0.0011	*	*	0.0004
AQ3	*	0.0004	0.0009	0.0004	*	*	0.0006
AQ5	*	0.0004	0.0006	*	*	*	*
PHASE 3							
AQ1	*	0.0004	0.0008	*	0.0005	*	0.0006
AQ3	*	0.0004	0.0026	*	*	*	0.0006
AQ5	*	0.0004	0.0011	*	*	*	0.0005
PHASE 4							
AQ1	0.0004	0.0015	0.0014	*	0.0009	*	*
AQ3	0.0014	0.0029	0.0047	0.0004	*	*	*
AQ5	0.0002	0.0012	0.0015	*	*	*	*

* All values below CRL

1 PPDDE = Dichlorodiphenylethane

2 PPDDT = Dichlorodiphenyltrichloroethane

Table 4.7-7 Summary of Basin F/IRA-F/RIFS Semi-Volatile Organic Compounds (SVOC) for Phases 1-4 (in $\mu\text{g}/\text{m}^3$)

	ALD	ATZ	CLDAN	PPDDE	FPDDT	DLDN	ENDRN	ISODR	MLTHN	PRTHN	SUPONA	CPMSO2
AVERAGE VALUES												
PHASE 1 (3/22/88 - 12/12/88)												
BF1	0.1913	ND	ND	ND	ND	0.1408	0.0719	0.0076	ND	ND	ND	ND
BF2	0.4579	ND	ND	ND	ND	0.2768	0.1209	0.0424	ND	ND	ND	ND
BF2C	0.5263	ND	ND	ND	ND	0.2475	0.1142	0.0584	ND	ND	ND	ND
BF3	0.0662	ND	ND	ND	ND	0.0808	0.0250	0.0017	ND	ND	ND	ND
BF4	0.0499	ND	ND	ND	ND	0.0477	0.0234	0.0030	ND	ND	ND	ND
BF5	0.0221	ND	ND	ND	ND	0.0193	0.0096	0.0011	ND	ND	ND	ND
BF6	0.0038	ND	ND	ND	ND	0.0083	0.0031	0.0004	ND	ND	ND	ND
BF7	0.0016	ND	ND	ND	0.0008	0.0038	0.0011	0.0003	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PHASE 2 - STAGE 1 (12/13/88 - 2/15/89)												
BF1	0.0106	ND	ND	ND	ND	0.0075	0.0041	0.0013	ND	ND	ND	ND
BF2	0.0154	ND	ND	ND	ND	0.0107	0.0044	0.0010	ND	ND	ND	ND
BF2C	0.0071	ND	0.0071	0.0013	0.0007	0.0079	0.0047	0.0008	ND	ND	ND	ND
BF3	0.0026	ND	ND	ND	ND	0.0032	0.0017	0.0005	ND	ND	ND	ND
BF4	0.0034	ND	ND	ND	ND	0.0027	0.0014	0.0007	ND	ND	ND	ND
BF5	0.0010	ND	ND	ND	ND	0.0010	0.0008	ND	ND	ND	ND	ND
BF6	0.0006	ND	ND	0.0007	ND	0.0012	0.0011	0.0003	ND	ND	ND	ND
BF7	ND	ND	ND	ND	ND	0.0008	0.0007	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PHASE 2 - STAGE 2 (2/16/89 - 5/5/89)												
BF1	0.0023	ND	ND	ND	ND	0.0057	0.0024	0.0003	ND	ND	ND	ND
BF2	0.0022	ND	ND	ND	ND	0.0076	0.0019	ND	ND	ND	ND	ND
BF2C	0.0017	ND	ND	0.0007	ND	0.0077	0.0023	ND	ND	ND	ND	ND
BF3	0.0006	ND	ND	ND	ND	0.0031	0.0010	ND	ND	ND	ND	ND
BF4	0.0007	ND	ND	ND	ND	0.0020	0.0010	ND	ND	ND	ND	ND
BF5	0.0005	ND	ND	ND	ND	0.0011	0.0007	ND	ND	ND	ND	ND
BF6	0.0004	ND	ND	ND	ND	0.0015	0.0008	ND	ND	ND	ND	ND
BF7	ND	ND	ND	ND	ND	0.0009	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	0.0003	ND	0.0002	0.0003	ND	ND	ND	ND	ND	ND
RIFS1D	ND	ND	0.0003	ND	ND	0.0005	ND	ND	ND	ND	ND	ND
RIFS2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 4.7-7 Summary of Basin F/IRA-F/RIFS Semi-Volatile Organic Compounds (SVOC) for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	ALD	ATZ	CLDAN	PPDDE	PPDDT	DLDN	ENDRN	ISODR	MLTHN	PRTHN	SUPONA	CPMSO2
AVERAGE VALUES												
PHASE 3 (5/6/89 - 9/30/89)												
FC1	0.0006	ND	0.0004	ND	ND	0.0047	0.0006	0.0002	ND	ND	ND	ND
FC2	0.0014	ND	0.0005	ND	0.0003	0.0121	0.0013	0.0004	ND	ND	ND	ND
FC2D	0.0016	ND	0.0005	ND	0.0002	0.0130	0.0013	0.0014	ND	ND	ND	ND
BF3/FC3	0.0004	ND	0.0005	ND	0.0002	0.0074	0.0006	0.0003	ND	ND	ND	ND
BF4/FC4	0.0005	ND	0.0004	ND	ND	0.0061	0.0007	0.0002	ND	ND	ND	ND
BF5	0.0002	ND	0.0002	ND	ND	0.0015	0.0003	ND	ND	ND	ND	ND
FC5	0.0006	ND	0.0003	ND	ND	0.0032	0.0003	ND	ND	ND	ND	ND
BF7	0.0002	ND	0.0004	ND	ND	0.0024	0.0004	0.0002	ND	ND	ND	ND
RIFS1	ND	ND	0.0003	ND	ND	0.0012	0.0002	ND	ND	ND	ND	ND
PHASE 4 (10/1/89 - 9/30/90)												
FC1	0.0005	ND	0.0003	ND	0.0002	0.0034	0.0004	0.0002	ND	ND	ND	0.0260
FC2	0.0012	ND	0.0004	ND	0.0004	0.0086	0.0009	0.0002	ND	ND	ND	ND
FC2D	0.0018	ND	0.0003	ND	0.0004	0.0098	0.0010	0.0002	ND	ND	ND	ND
FC3	0.0004	ND	0.0003	0.0002	0.0003	0.0034	0.0004	0.0002	ND	ND	ND	ND
FC4	0.0007	ND	0.0003	ND	0.0002	0.0052	0.0005	0.0002	ND	ND	ND	ND
FC5	0.0004	ND	0.0003	ND	0.0002	0.0029	0.0005	0.0002	ND	ND	ND	0.0288

Legend: ALDRN Aldrin
 ATZ Atrazine
 CLDAN Chlordane
 PPDDE Dichlorodiphenylethane
 PPDDT Dichlorodiphenyltrichlorethane
 DLDRN Dieldrin
 ENDRN Endrin
 ISODR Isodrin
 MLTHN Malathion
 PRTHN Parathion
 SUPONA Supona
 CPMSO2 Chlorophenyl Methylsulfone

Table 4.7-7 Summary of Basin F/IRA-F/RIFS Semi-Volatile Organic Compounds (SVOC) for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

ALD	ATZ	CLDAN	PPDDE	PPDDT	DLDN	ENDRN	ISODR	MLTHN	PRTHN	SUPONA	CPMSO2
24-HOUR MAXIMUM VALUES											
PHASE 1 (3/22/88 - 12/12/88)											
BF1	0.8366	ND	ND	ND	0.4904	0.2497	0.0604	ND	ND	ND	
BF2	2.8290	ND	ND	ND	2.2960	0.9020	0.8160	ND	ND	ND	
BF2C	2.5773	ND	ND	ND	2.1478	1.0954	0.9450	ND	ND	ND	
BF3	0.4288	ND	ND	ND	1.6568	0.5458	0.0226	ND	ND	ND	
BF4	0.3478	ND	ND	ND	0.3265	0.2591	0.1136	ND	ND	ND	
BF5	0.1723	ND	ND	ND	0.0499	0.0275	0.0080	ND	ND	ND	
BF6	0.0369	ND	ND	ND	0.0256	0.0093	0.0016	ND	ND	ND	
BF7	0.0124	ND	ND	0.0017	0.0479	0.0050	0.0007	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
PHASE 2 - STAGE 1 (12/13/88 - 2/15/89)											
BF1	0.083C	ND	ND	ND	0.0361	0.0223	0.0114	ND	ND	ND	
BF2	0.1244	ND	ND	ND	0.0355	0.0147	0.0100	ND	ND	ND	
BF2C	0.0210	ND	0.0060	0.0010	0.0310	0.0130	0.0020	ND	ND	ND	
BF3	0.0234	ND	ND	ND	0.0130	0.0061	0.0034	ND	ND	ND	
BF4	0.0321	ND	ND	ND	0.0099	0.0042	0.0078	ND	ND	ND	
BF5	0.0080	ND	ND	ND	0.0030	0.0010	ND	ND	ND	ND	
BF6	0.0020	ND	0.0020	ND	0.0040	0.0040	0.0004	ND	ND	ND	
BF7	ND	ND	ND	ND	0.0010	0.0010	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PHASE 2 - STAGE 2 (2/16/89 - 5/5/89)											
BF1	0.0190	ND	ND	ND	0.0190	0.0070	0.0010	ND	ND	ND	
BF2	0.0230	ND	ND	ND	0.0340	0.0100	ND	ND	ND	ND	
BF2C	0.0090	ND	0.0010	ND	0.0330	0.0100	ND	ND	ND	ND	
BF3	0.0050	ND	ND	ND	0.0110	0.0030	ND	ND	ND	ND	
BF4	0.0040	ND	ND	ND	0.0070	0.0040	ND	ND	ND	ND	
BF5	0.0020	ND	ND	ND	0.0030	0.0010	ND	ND	ND	ND	
BF6	0.0010	ND	ND	ND	0.0050	0.0010	ND	ND	ND	ND	
BF7	ND	ND	ND	ND	0.0017	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	0.0007	ND	0.0009	ND	ND	ND	ND	ND	ND
RIFS1D	ND	0.0006	ND	0.0007	0.0009	ND	ND	ND	ND	ND	ND
RIFS2	ND	ND	ND	ND	0.0009	ND	ND	ND	ND	ND	ND

Table 4.7-7 Summary of Basin F/IRA-F/RIFS Semi-Volatile Organic Compounds (SVOC) for Phases 1-4 (in $\mu\text{g}/\text{m}^3$) (continued)

	ALD	ATZ	CLDAN	FPDDE	FPDDT	DLDN	ENDRN	ISODR	MLTHN	PRTHN	SUPONA	CPMSO2
24-HOUR MAXIMUM VALUES												
PHASE 3 (5/6/89 - 9/30/89)												
FC1	0.0041	ND	0.0010	ND	ND	0.0188	0.0015	0.0005	ND	ND	ND	ND
FC2	0.0103	ND	0.0015	ND	0.0010	0.0444	0.0045	0.0011	ND	ND	ND	ND
FC2D	0.0088	ND	0.0011	ND	0.0006	0.0424	0.0034	0.0106	ND	ND	ND	ND
BF3/FC3	0.0017	ND	0.0019	ND	0.0004	0.0240	0.0021	0.0006	ND	ND	ND	ND
BF4/FC4	0.0016	ND	0.0014	ND	ND	0.0179	0.0022	0.0005	ND	ND	ND	ND
BF5	0.0004	ND	0.0005	ND	ND	0.0023	0.0004	ND	ND	ND	ND	ND
FC5	0.0033	ND	0.0007	ND	ND	0.0159	0.0008	ND	ND	ND	ND	ND
BF7	0.0004	ND	0.0010	ND	ND	0.0053	0.0006	0.0005	ND	ND	ND	ND
RIFS1	ND	ND	0.0007	ND	ND	0.0033	0.0004	ND	ND	ND	ND	ND
PHASE 4 (10/1/89 - 9/30/90)												
FC1	0.0079	ND	0.0015	ND	0.0006	0.0310	0.0022	0.0004	ND	ND	ND	0.0360
FC2	0.0300	ND	0.0023	ND	0.0041	0.0720	0.0063	0.0011	ND	ND	ND	ND
FC2D	0.0270	ND	0.0015	ND	0.0038	0.0640	0.0064	0.0005	ND	ND	ND	ND
FC3	0.0035	ND	0.0023	0.0006	0.0014	0.0270	0.0039	0.0007	ND	ND	ND	ND
FC4	0.0095	ND	0.0014	ND	0.0020	0.0430	0.0034	0.0004	ND	ND	ND	ND
FC5	0.0073	ND	0.0018	ND	0.0009	0.0260	0.0067	0.0004	ND	ND	ND	0.0840
Legend:												
ALDRN	Aldrin	ENDRN	Endrin			ISODR	Isodrin					
ATZ	Atrazine	MLTHN	Malathion			PRTHN	Parathion					
CLDAN	Chlordane	SUPONA	Supona			CPMSC2	Chlorophenyl Methylsulfone					
FPDDE	Dichlorodiphenylethane											
FPDDT	Dichlorodiphenyltrichlorethane											
DLDRN	Dieldrin											

Table 4.7-7 provides a detailed summary for each SVOC target compound for each remediation phase at the IRA-F monitoring sites. It can be seen from these data that a number of SVOCs were measured at higher concentrations in the vicinity of Basin F during the Phase 1 period. These compounds then decreased significantly during the Phase 3 and Phase 4 post-remedial periods. Specific SVOCs observed at higher levels during the remediation activities were aldrin, dieldrin, endrin and isodrin. In all cases, concentrations of these constituents were higher in the immediate vicinity of Basin F activities and decreased to low levels with distance from the Basin F potential source.

Several SVOCs analyzed including atrazine, malathion, parathion and Supona were nondetectable, or measured at very low levels at all Basin F sites for all phases of the remedial program, suggesting that Basin F was not a potential source of these compounds.

Figures 4.7-5 through 4.7-8 show a bar graph depiction of the concentration levels of aldrin, dieldrin, endrin and isodrin for each phase of the remediation activities and after completion of the cleanup program. Concentration levels were highest during Phase 1 at those stations immediately adjacent to Basin F, with a significant decrease with distance from the source. During Phase 2, Phase 3, and Phase 4 concentrations decreased with the exception of dieldrin at all monitoring sites to levels that are considered typical regional background concentrations. Dieldrin levels were slightly higher at several Basin F stations during Phases 3 and 4 than Phase 2. This may be a seasonal influence or a minor residual effect from Basin F. SVOC results, however, were considerably below Phase 1 concentrations and well below contaminant health guidelines discussed in Section 4.7.4.

As in the case of metals and VOCs, another approach to assessing remedial progress for SVOCs is to consider Basin F impacts that were observed on individual days during the remedial and post-remedial periods. All Basin F air monitoring during the Phase 1 period was conducted for worst-case 24-hour periods based on dispersion model analysis and remedial activity. An example of the dispersion of SVOCs resulting from Basin F remedial activities is shown in Figure 4.7-9. This figure shows Phase 1 SVOC concentrations for August 23, 1988, with X/Q dispersion values overlaying the monitoring data for seven Basin F stations. Again, this type of analysis identifies, to the fullest extent, the potential dispersion of contaminants resulting from remedial actions.

During this sampling period, winds followed basically a typical diurnal cycle, with south to north flow during the night and north to south during the day. Wind speeds were mostly light and the maximum temperature was 88°F. On this day there were no detectable amounts of any pesticides at the upwind off-site Station BF7. Concentrations of aldrin, dieldrin, endrin and isodrin ranged from non-

Aldrin Results By Phase

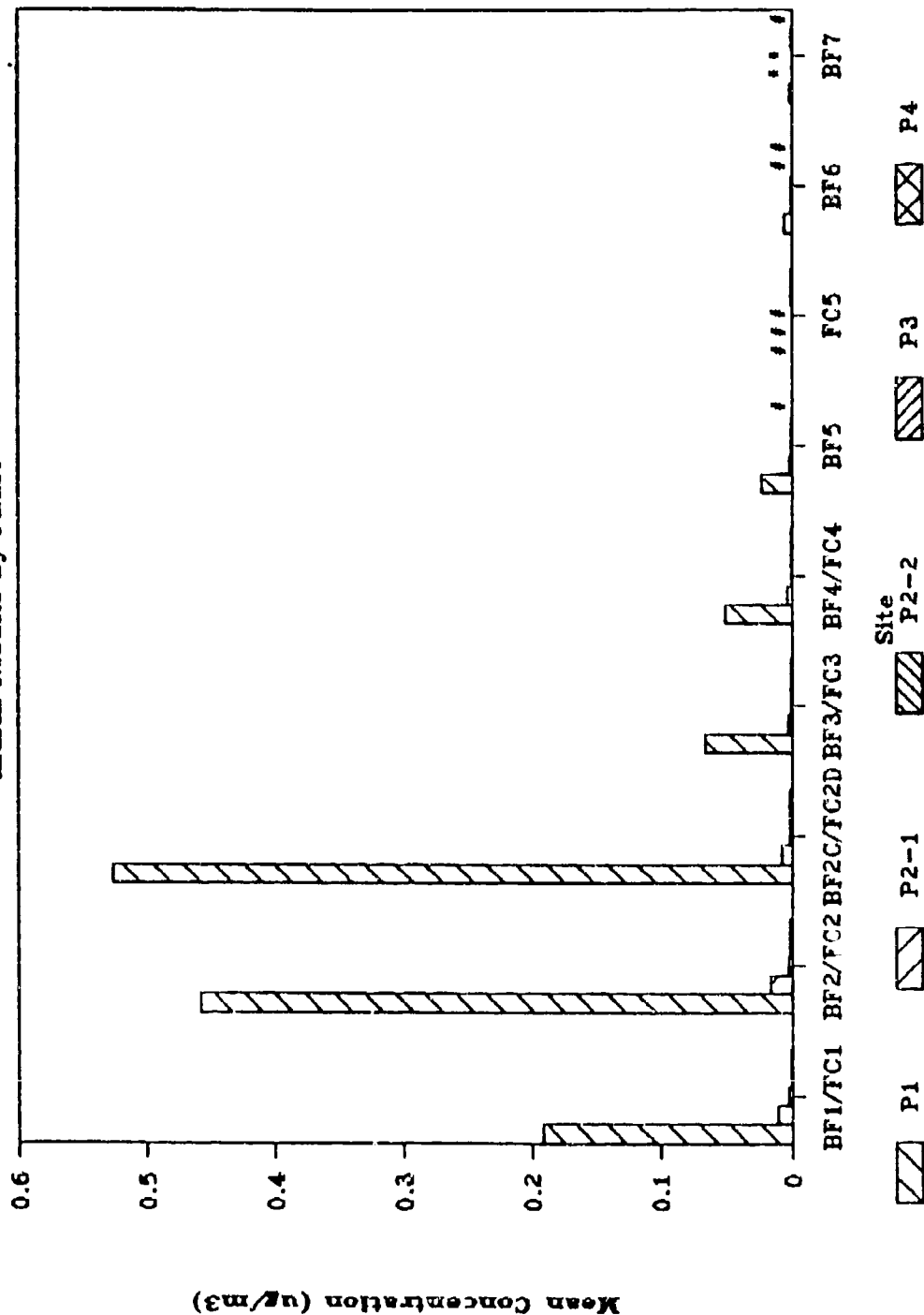


Figure 4.7-5

Aldrin Results by Phase

CMP AR FY90

Prepared for :

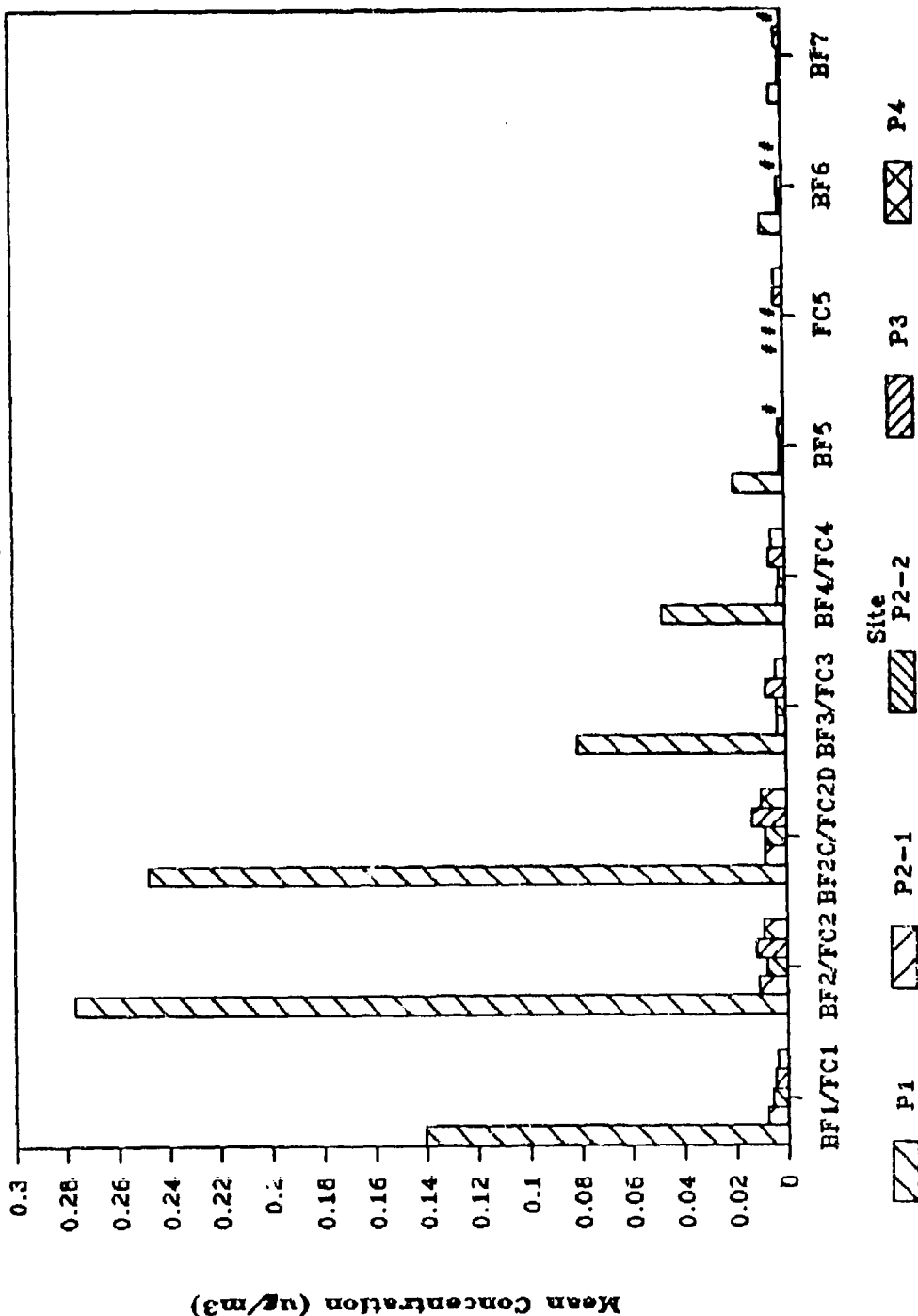
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

- NO SAMPLES TAKEN DURING THIS PHASE
* - NOT DETECTED DURING THIS PHASE

Dieldrin Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

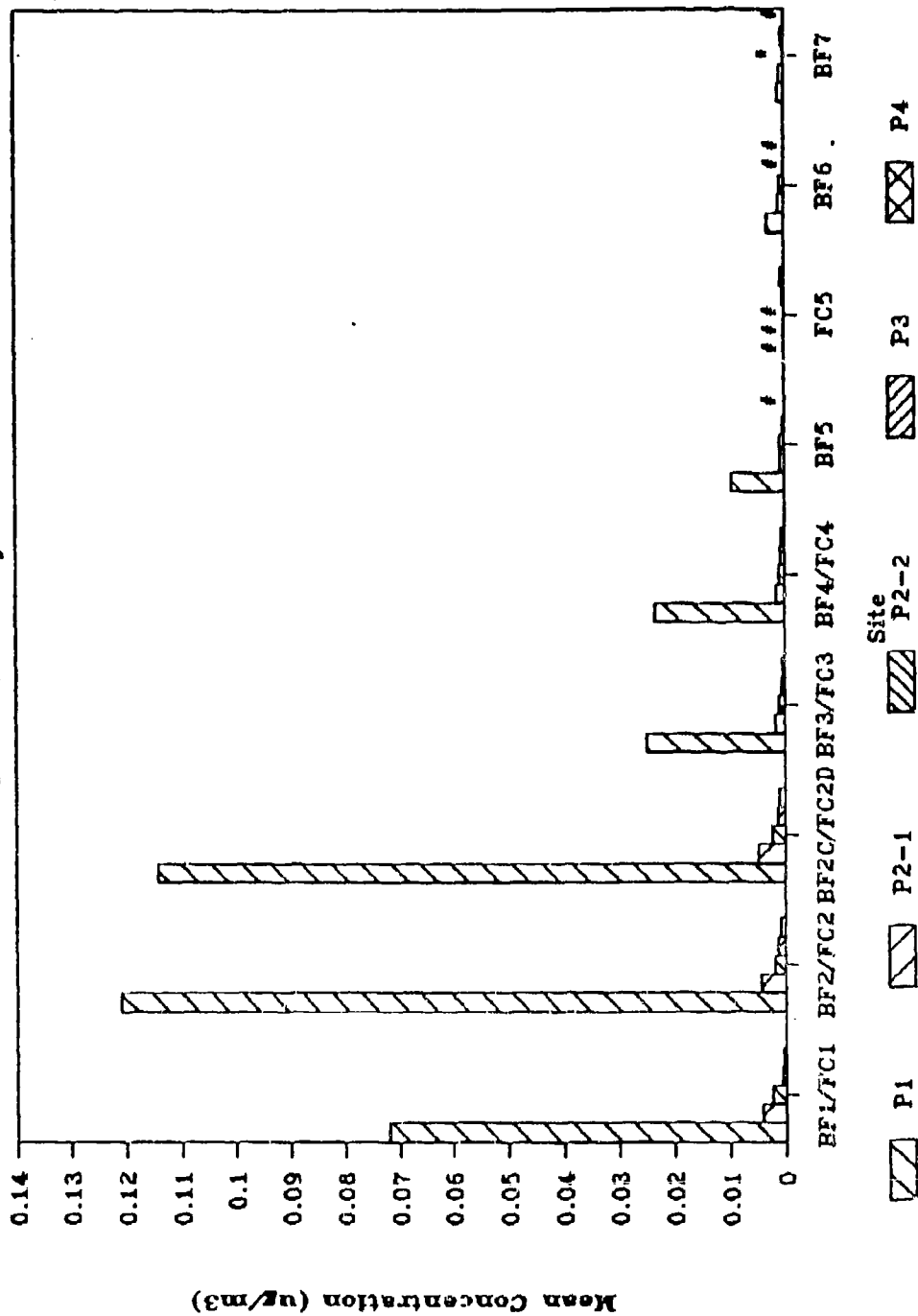
Figure 4.7-8

Dieldrin Results by Phase

CMP AR FY90

- NO SAMPLES TAKEN DURING THIS PHASE
* - NOT DETECTED DURING THIS PHASE

Endrin Results By Phase



- NO SAMPLES TAKEN DURING THIS PHASE
 * - NOT DETECTED DURING THIS PHASE

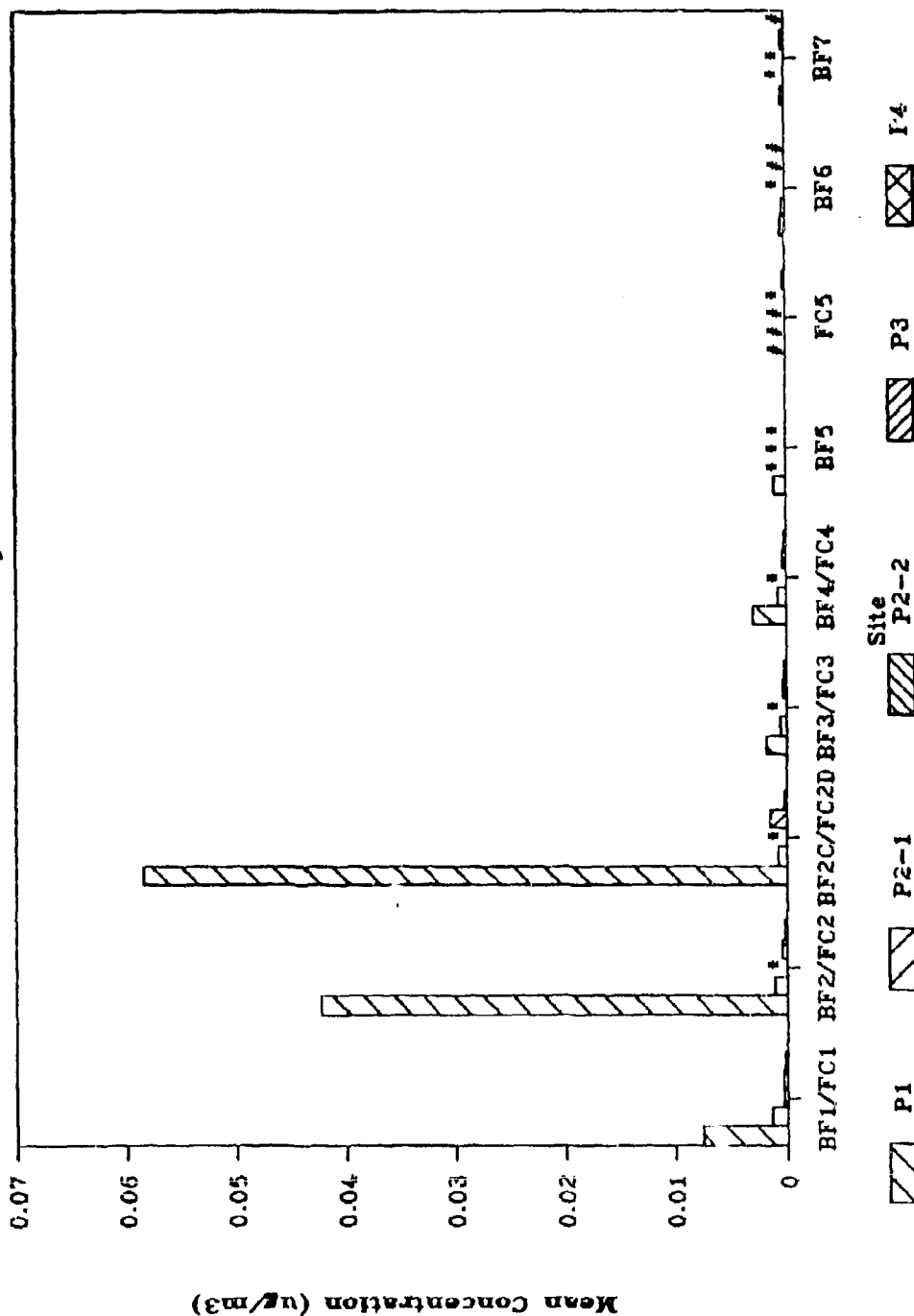
Prepared for :
 U.S. Army Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by :
 R.L. Stollar & Associates, Inc.
 Ebasco Services, Inc.

Figure 4.7-7

Endrin Results by Phase

CMP AR FY90

Isodrin Results By Phase



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

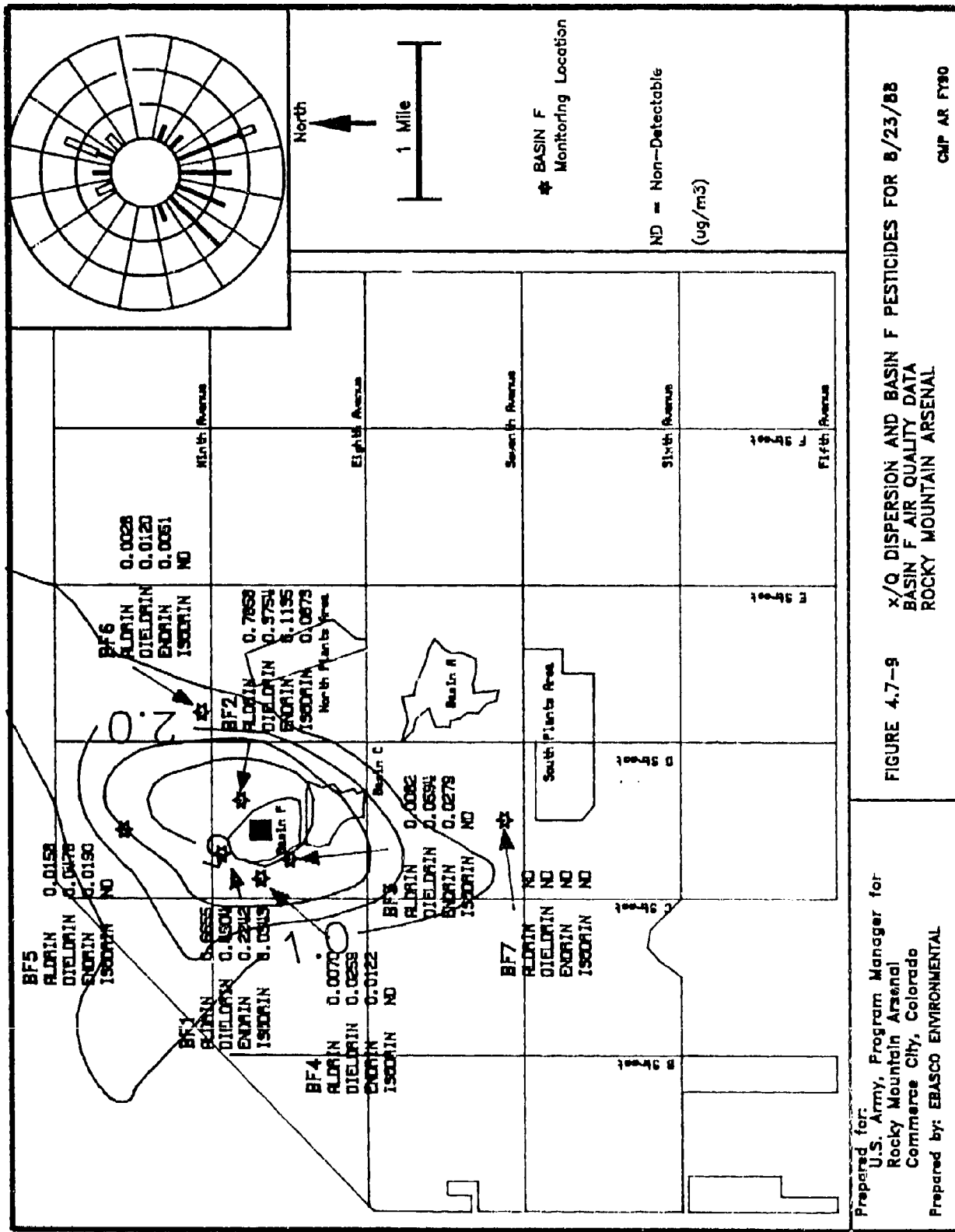
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 4.7-8

Isodrin Results by Phase

CMP AR FY90

- NO SAMPLES TAKEN DURING THIS PHASE
* - NOT DETECTED DURING THIS PHASE



Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: ERASCO ENVIRONMENTAL

FIGURE 4.7-9

X/Q DISPERSION AND BASIN F PESTICIDES FOR 8/23/88
 BASIN F AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

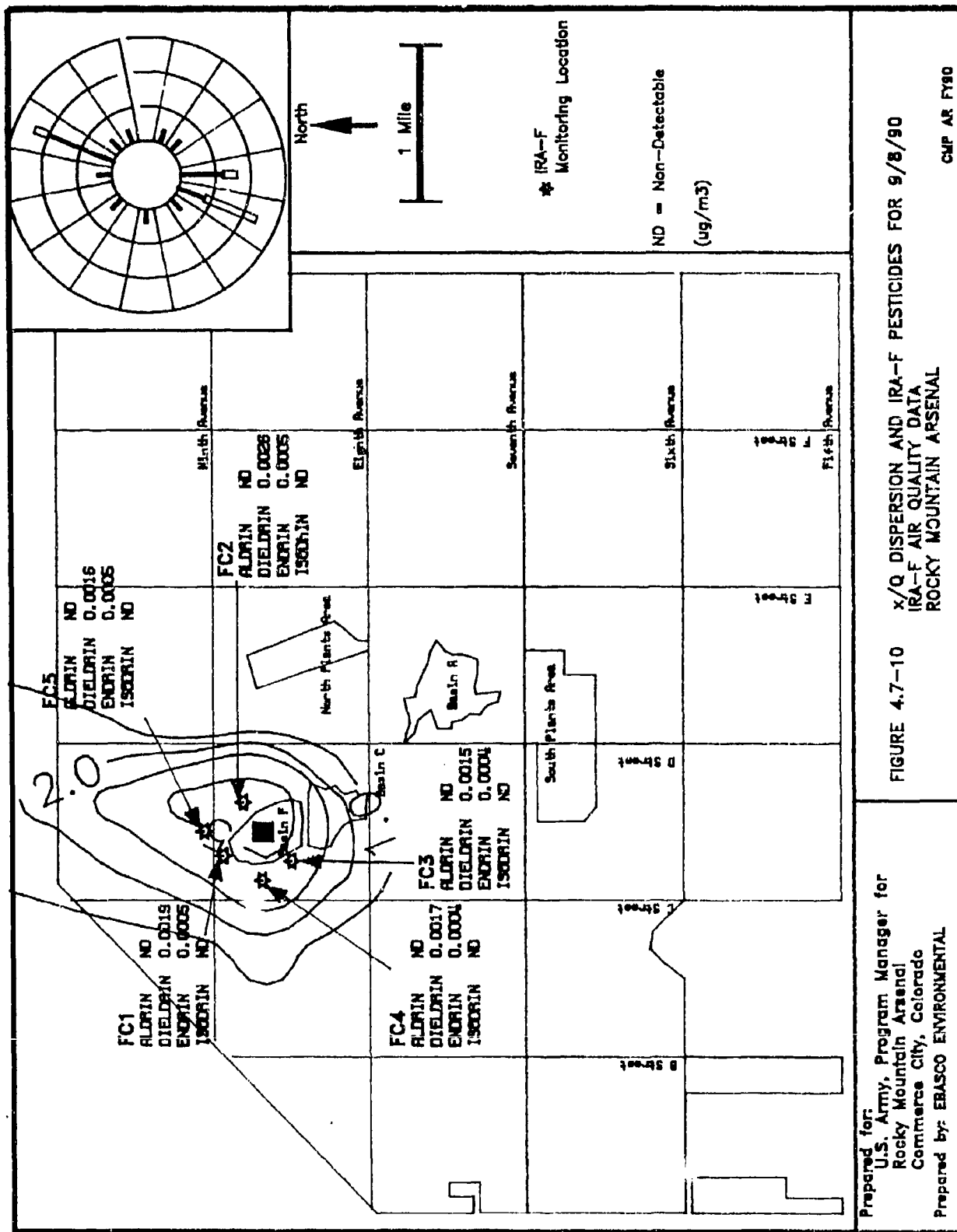
CMP AR FY90

detectable to $0.7858 \mu\text{g}/\text{m}^3$ at the Basin F perimeter sites, but dropped considerably in value to less than $0.0478 \mu\text{g}/\text{m}^3$ at the further downwind sites BF5 and BF6. The actual concentrations followed quite closely the predicted dispersion pattern. The results indicate Basin F was clearly a source of these pesticides during the remediation phase.

A Phase 4 sample period with similar dispersion characteristics to the Phase 1 example was September 7-8, 1990, as shown in Figure 4.7-10. The winds during this period reflected a typical diurnal pattern, with light to moderate south-southwesterly flow at night and light north-northeasterly flow during the day. Maximum temperatures reached the low 80s. Contaminant levels for aldrin, dieldrin, and endrin were significantly lower on this day than on the comparable Phase 1 day. Apparently, the Basin F area was still a minor source of several pesticides on this Phase 4, post-remediation day, although the concentrations were much smaller than during the remediation period.

4.7.3.3 Combined CMP and Basin F Data Analyses

Individual CMP and Basin F SVOC monitoring data for the phases of the remedial monitoring programs have been shown in Tables 4.7-5 and 4.7-7. Figures 4.7-11, 4.7-11A and 12 provide a comparison of average and 24-hour maximum CMP and Basin F SVOC data across the Arsenal complex for the Phase 1 remedial and Phase 4 post-remedial periods. The wind roses reflecting potential transport of contaminants are also shown in these figures. As noted from the previous discussions, the Phase 1 data show impacts of aldrin, dieldrin, endrin and isodrin immediately adjacent and downwind from Basin F. Farther downwind, SVOC concentrations decreased and became minimal at the RMA perimeter sites as represented by the CMP data. During Phase 4, SVOC levels decreased significantly both in the immediate vicinity of Basin F as well as downstream. Nevertheless, the pattern shown on Figure 4.7-12 indicates that the Basin F area may have remained a very weak source of pesticides during the Phase 4 period. Several pesticides were slightly higher in the vicinity of Basin F than at perimeter and other interior monitoring sites. In Figure 4.7-12, OCP results from the CMP perimeter sites were also employed, providing a more sensitive analysis of potential pesticide levels; all average values during this period, however, were either non-detectable or less than $0.001 \mu\text{g}/\text{m}^3$, suggesting little or no impacts from Basin F post-operations at the boundaries of the Arsenal.



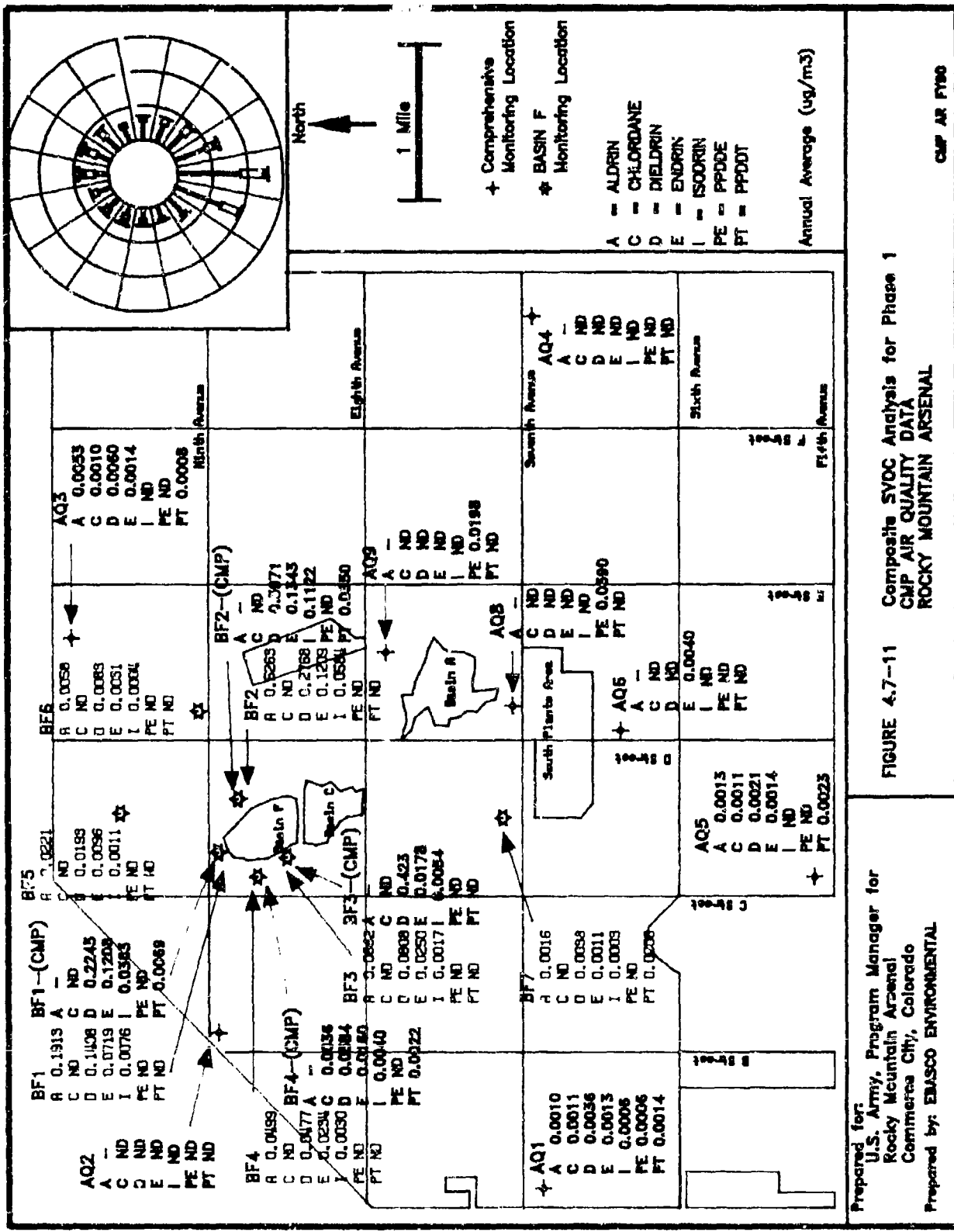
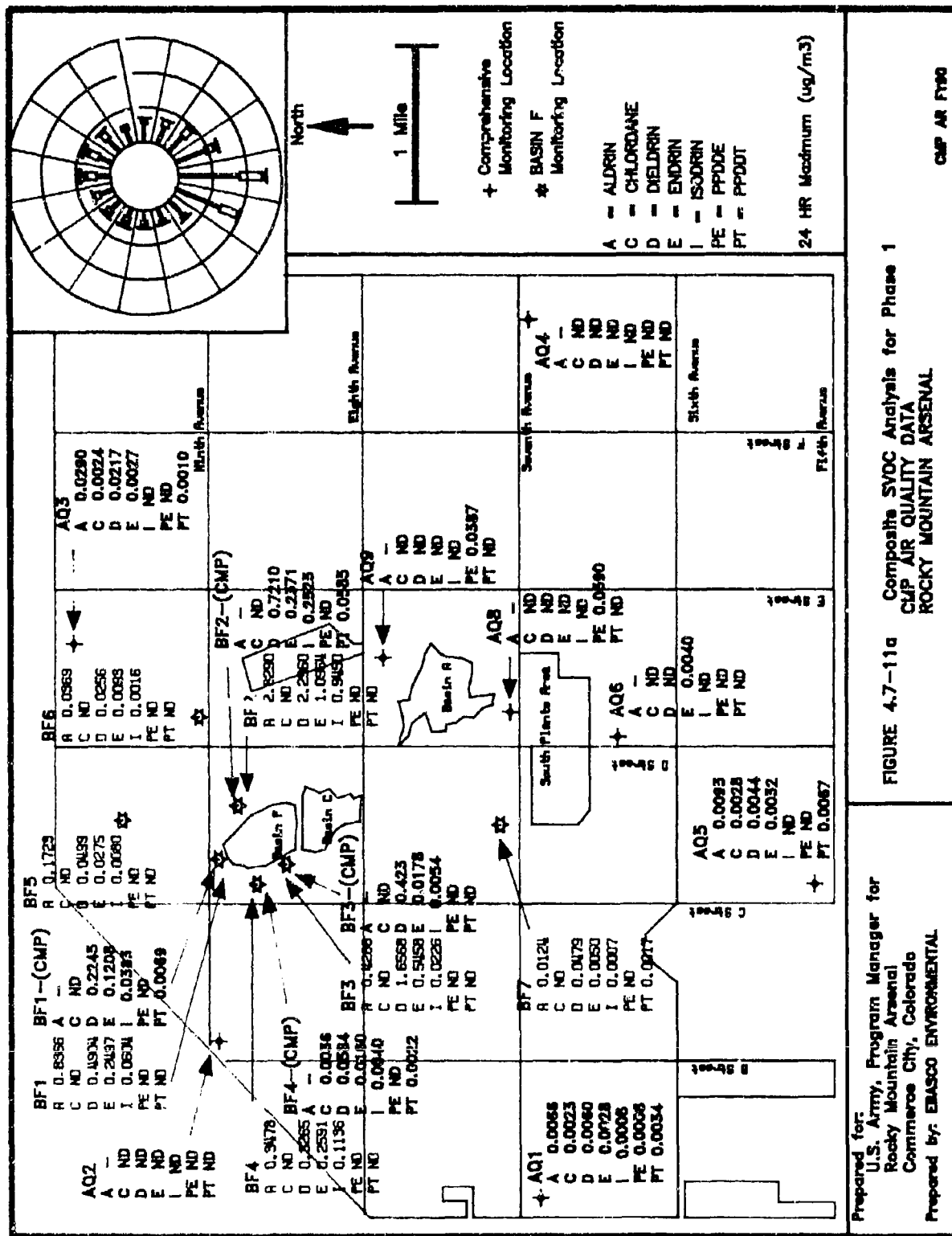
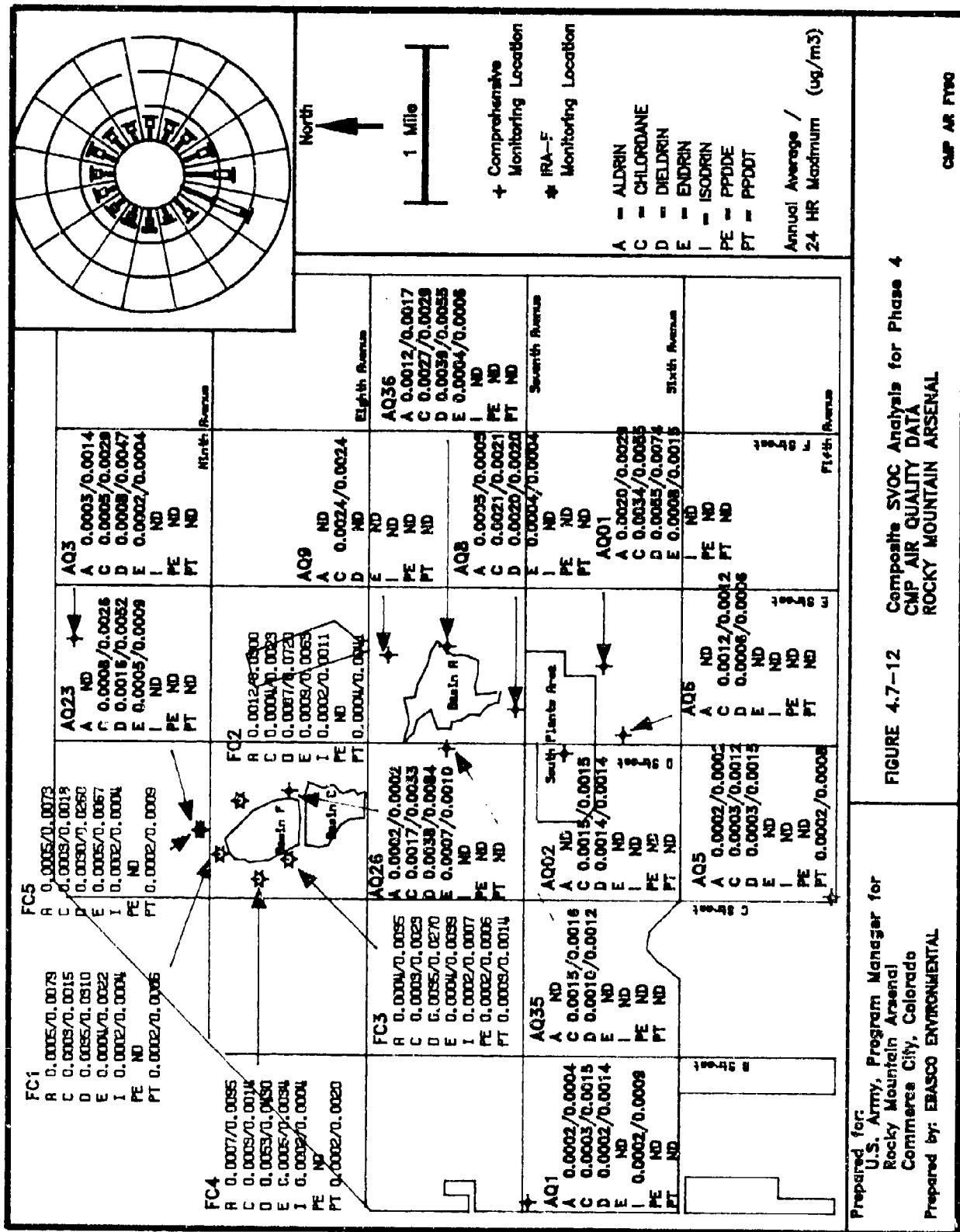


FIGURE 4.7-11 Composite SVOC Analysis for Phase 1
CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

Prepared for:
U.S. Army, Program Manager for
Rocky Mountain Arsenal
Commercia City, Colorado
Prepared by: EMASCO ENVIRONMENTAL

CMP AIR PT80





In summary, the data indicate that Basin F was the principal emitter of several potential SVOC pesticides during remediation activities. These impacts were local and decreased significantly beyond the immediate vicinity of Basin F. Downwind monitoring stations reflected higher concentration levels than upwind stations; however, the more distant stations, as reflected by the CMP perimeter locations, indicated low to minimal SVOC levels. During the Phase 3 and Phase 4 post-remedial periods, pesticide levels appeared to decrease significantly, although very low levels of aldrin, dieldrin, and isodrin continued to be measured near the Basin F area.

4.7.4 SUMMARY OF RESULTS AND ASSESSMENT OF SVOC TOXICITY LEVELS

Table 4.7-8 shows the locations of both maximum long-term (annual) average and maximum short-term (24-hour) SVOC concentrations for the combined CMP and Basin F data analyses results for the phases of remediation. It is noted that almost all of the highest concentrations occurred in the initial remediation phase. Also, highest concentrations occurred most often at station BF2, directly downwind from Basin F.

In order to assess the significance of the measured SVOC concentrations with respect to health standards and guidelines, a literature search was conducted using references identical to those identified in the metals and VOC assessments.

A tabulation of guideline concentrations for comparison with measured SVOC concentrations is presented in Table 4.7-9; refer to Section 4.6.4 for a more detailed description of the contents of this table. The Phase 1 and Phase 2 remediation periods are grouped together and the Phase 3 and Phase 4 post-remedial periods are also shown separately. Again, the comparison is very conservative because all CMP and Basin F data reflect averages of selected *worst-case* conditions. Nevertheless, this comparison is useful for identifying potential concerns during remedial operations and areas where CMP monitoring emphasis or remedial mitigation measures may be most appropriately directed. A review of the CMP and IRA-F target analyte results and potential toxic concerns follows.

Table 4.7-8 Maximum Average Long-Term and Short-Term Semi-Volatile Organic Compounds Concentrations (in $\mu\text{g}/\text{m}^3$)

SVOC	Maximum Long-Term* Average	Location	Phase	Maximum Short-Term Concentration	Location	Phase
Aldrin	0.5263	BF2	P1	2.8290	BF2	P1
Chlordane	0.0071	BF2	P2-S1	0.0360	BF2	P2-S1
Dieldrin	0.3971	CMP/BF2	P1	2.2960	BF2	P1
Endrin	0.1343	CMP/BF2	P1	1.0954	BF2	P1
Isodrin	0.1122	CMP/BF2	P1	0.9450	BF2	P1
PPDDE	0.0390	AQ8	P1	0.0390	AQ8	P1
PPDDT	0.0350	CMP/BF2	P1	0.0585	CMP/BF2	P1
Atrazine	ND	-		ND	-	
Malathion	ND	-		ND	-	
Parathion	0.1311	CMP/BF2	P1	0.2099	CMP/BF2	P1
Supona	ND	-		ND	-	

* Several maximum long-term averages provided in this table represent limited sampling from the CMP high event programs. More extensive long-term monitoring results for the Basin F Monitoring Program are shown in Table 4.7-7.

Legend: PPDDE = Dichlorodiphenylethane
 PPDDT = Dichlorodiphenyltrichloroethane
 P1 = Phase 1
 P2-S1 = Phase 2-Stage 1
 P2-S2 = Phase 2-Stage 2
 P3 = Phase 3
 P4 = Phase 4

The highest 24-hour aldrin concentration, $2.83 \mu\text{g}/\text{m}^3$ was measured at BF2 during Phase 1. This level was slightly greater than the recommended typical 24-hour guideline of $2.5 \mu\text{g}/\text{m}^3$. This high level was very localized in the immediate vicinity of remedial work on the northeast perimeter of the Basin F Exclusion Zone. The maximum 24-hour, or short-term, levels at the other perimeter sites ranged from $0.35 \mu\text{g}/\text{m}^3$ to $0.84 \mu\text{g}/\text{m}^3$. At the more distant Basin F sites, BF5, BF6 and BF7, maximum 24-hour aldrin values were $0.17 \mu\text{g}/\text{m}^3$, $0.04 \mu\text{g}/\text{m}^3$ and $0.01 \mu\text{g}/\text{m}^3$ respectively, or less than 7 percent of the short-term guideline. The CMP SVOC sampling did not measure aldrin, but aldrin measured under the organics in total suspended particulates program using the pesticide analytical method measured 24-hour maximum aldrin values of $0.001 \mu\text{g}/\text{m}^3$ to $0.005 \mu\text{g}/\text{m}^3$ during Phase 1, or about 0.2 percent of the guideline (at RMA boundaries).

Table 4.7-9 RMA Target Semi-Volatile Organic Compounds and OCP Comparisons to Health Guidelines

Target Name	CAS #	Short-term		Typical Guidelines (µg/m ³)	RMA Phases 1 and 2				RMA OCP Boundary Evaluation							
		TLV (ppm)	TLV/20 (µg/m ³)		Avg ADI	1 Yr Avg ADI	Chronic Subchronic	Maximum Conc.*		% of Guideline	Max. Boundary Conc. (µg/m ³)		% of Guideline			
								24-Hr	Long-Term		24-Hr	Long-Term		24-Hr	Long-Term	
Aldrin	309-00-2	0.015	0.60		0.105	2.5	0.595	2.8290	0.5263	>100	88	0.0290*	0.0053*	1	<1	
Chlordane	57-74-9	0.027	1.19		0.175	5	1.19	0.0360	0.0071	<1	<1	0.0028	0.0011	<1	<1	
Dieldrin	60-57-1	0.015	0.60			4	0.595	2.2960	0.3971	57	67	0.0217	0.0060	<1	1	
Endrin	72-20-8	0.006	0.24			1.6	0.238	1.0954	0.1343	68	47	0.0032	0.0014	<1	<1	
Isodrin	465-73-6							0.9450	0.1122				0.0008	0.0006		
PPDDE	72-55-9						1.8	0.0390	0.0390	<1	2	0.0008	0.0006	<1	<1	
PPDDT	50-29-3	0.063	2.38		1.75	10	2.381	0.0585	0.0350	ND	1	ND	ND	ND	ND	
Atrazine	1912-24-9	0.519	11.90			80		ND	ND	ND	ND	ND	ND	ND	ND	
Malathion	121-75-5	0.679	23.81		70	100	33.3	ND	ND	ND	ND	ND	ND	ND	ND	
Parathion	56-38-2	0.008	0.24			1.6	0.238	0.2099	0.1311	13	55	ND	ND	ND	ND	
Supona	2701-86-2							ND	ND				ND	ND		
Phases 3 and 4																
Aldrin	309-00-2	0.015	0.60		0.105	2.5	0.595	0.0103	0.0027	<1	<1	ND	ND	ND	ND	
Chlordane	57-74-9	0.027	1.19		0.175	5	1.19	0.0019	0.0008	<1	<1	ND	ND	ND	ND	
Dieldrin	60-57-1	0.015	0.60			4	0.595	0.0444	0.0130	1	2	ND	ND	ND	ND	
Endrin	72-20-8	0.006	0.24			1.6	0.238	0.0045	0.0017	<1	<1	ND	ND	ND	ND	
Isodrin	465-73-6							0.0106	0.0039			ND	ND	ND	ND	
PPDDE	72-55-9						1.8	ND	ND		ND	ND	ND	ND	ND	
PPDDT	50-29-3	0.063	2.38		1.75	10	2.381	0.0010	0.0007	<1	<1	ND	ND	ND	ND	
Atrazine	1912-24-9	0.519	11.90			80		ND	ND	ND	ND	ND	ND	ND	ND	
Malathion	121-75-5	0.679	23.81		70	100	33.3	ND	ND	ND	ND	ND	ND	ND	ND	
Parathion	56-38-2	0.008	0.24			1.6	0.238	ND	ND	ND	ND	ND	ND	ND	ND	
Supona	2701-86-2							ND	ND			ND	ND	ND	ND	

* Using OCP aldrin monitoring results. Maximum long-term averages for dieldrin, endrin, isodrin, PPDDT and parathion were derived from limited sampling taken from the OCP high event program. More extensive long-term monitoring results for the Basin F monitoring program are shown in Table 4.7-7.

Legend: PPDDE = Dichlorodiphenylethane
 PPDDT = Dichlorodiphenyltrichloroethane
 ADI = Acceptable Daily Intake
 TLV = Threshold Limit Value

The maximum average aldrin concentration of $0.53 \mu\text{g}/\text{m}^3$ was measured at BF2 and was 88 percent of the typical annual guideline of $0.595 \mu\text{g}/\text{m}^3$. This average level was observed during Phase 1, which was an approximately 7-month sampling period. If the more restrictive ADI chronic guideline of $0.105 \mu\text{g}/\text{m}^3$ is used, aldrin at BF2 would be above the recommended significant level. However, it should be stressed that these data represent selected worst-case monitoring periods during peak remedial activity and do not necessarily correspond to the annual ambient concentrations for which the guideline was established. Nevertheless, personnel working routinely in the vicinity of this location wore protective clothing and respirators. There were no other locations that exceeded the annual guidelines. Average concentrations again fell off quickly from the BF2 monitoring location and decreased significantly by Phases 3 and 4. Long-term average concentrations at the CMP boundary stations were less than 1 percent of the typical guideline.

Several SVOCs detected near Basin F followed the same patterns as aldrin, although aldrin indicated the highest percentages with respect to toxic guidelines. The highest 24-hour endrin measurement was $1.10 \mu\text{g}/\text{m}^3$ at BF2 during Phase 1, or 68 percent of the 24-hour guideline of $1.6 \mu\text{g}/\text{m}^3$. Other Basin F perimeter 24-hour maximum levels ranged from $0.26 \mu\text{g}/\text{m}^3$ to $0.55 \mu\text{g}/\text{m}^3$ during Phase 1, decreasing to less than $0.01 \mu\text{g}/\text{m}^3$ during Phases 2, 3, and 4. Maximum levels at outlying RMA boundary stations measured below $0.01 \mu\text{g}/\text{m}^3$, or less than 1 percent of the short-term guideline.

The maximum long-term average endrin concentration was $0.13 \mu\text{g}/\text{m}^3$ at BF2 (CMP) during Phase 1, or 47 percent of the annual guideline of $0.238 \mu\text{g}/\text{m}^3$. This represents the mean of limited CMP samples specifically selected to capture high events. More extensive Basin F monitoring at the same location (BF2) shows a mean value of $0.12 \mu\text{g}/\text{m}^3$. Downstream Basin F stations were less than $0.01 \mu\text{g}/\text{m}^3$, which is only 4 percent of the annual guideline. At the RMA boundaries, endrin averaged below $0.0014 \mu\text{g}/\text{m}^3$, or less than 1 percent of the annual guideline.

The maximum 24-hour dieldrin concentration of $2.30 \mu\text{g}/\text{m}^3$ was measured under the Basin F program at BF2 during Phase 1; this was 57 percent of the 24-hour guideline of $4 \mu\text{g}/\text{m}^3$. The 24-hour maximum values at other Basin F perimeter locations ranged from $1.66 \mu\text{g}/\text{m}^3$ at BF3 to $0.33 \mu\text{g}/\text{m}^3$ at BF4. Dieldrin at downstream Basin F stations ranged from $0.03 \mu\text{g}/\text{m}^3$ to $0.05 \mu\text{g}/\text{m}^3$, or about 2 percent of the 24-hour guideline. Dieldrin levels decreased significantly during the Phase 2, 3, and 4 periods. Concentrations of 24-hour dieldrin at CMP boundary stations were in the range of $0.02 \mu\text{g}/\text{m}^3$, or less than 1 percent of the 24-hour guideline.

The highest average dieldrin concentration was $0.40 \mu\text{g}/\text{m}^3$ at BF2 (CMP) during Phase 1. This was 67 percent of the annual guideline of $0.59 \mu\text{g}/\text{m}^3$ but again represented the mean of only samples which are specifically selected to capture high events. More extensive Basin F monitoring resulted in a maximum long-term average of $0.27 \mu\text{g}/\text{m}^3$. Dieldrin at downstream Basin F stations ranged from below $0.01 \mu\text{g}/\text{m}^3$ to $0.02 \mu\text{g}/\text{m}^3$, or about 3 percent of the annual guideline. RMA boundary sites based on both SVOC and OCP samples measured dieldrin concentrations at or below $0.006 \mu\text{g}/\text{m}^3$ during all phases, or about 1 percent of the long-term guideline.

Isodrin was detected only during Phase 1 at the CMP sites. The maximum average was $0.1122 \mu\text{g}/\text{m}^3$ and occurred at CMP/BF2. The maximum 24-hour concentration of $0.9450 \mu\text{g}/\text{m}^3$ was measured at BF2 during Phase 1. Levels of isodrin continued to decrease through Phase 2 Stage 2, but showed a slight increase for Phase 3. Isodrin was detected at RMA at low levels in the vicinity of Basin F during Phase 4. There are no guidelines listed for isodrin in Table 4.7-9.

Aldrin, endrin and dieldrin were the three principal pesticides measured during the Basin F monitoring program and the CMP. Parathion was detected one time during Phase 1 at the BF2 (CMP) station. The concentration was $0.21 \mu\text{g}/\text{m}^3$, or about 13 percent of the short-term guideline. All other samples were nondetectable for parathion. Chlordane, isodrin, PPDDE and PPDDT were measured at considerably lesser values and were all less than 1 percent of the short-term and long-term guidelines.

Several target SVOC compounds analyzed under the CMP and Basin F air monitoring programs were not detected. These included Supona, malathion and atrazine.

In summary, Basin F appeared to be a potential source of several SVOC compounds measured under the CMP and Basin F monitoring programs. In particular these included aldrin, endrin and dieldrin. Highest levels were clustered around Basin F. Monitoring Station BF2, on the northeast perimeter of the basin measured the highest concentrations for most SVOC compounds; these levels were close to toxic guidelines for selected worst-case monitoring scenarios. All other monitoring stations were well below the guidelines; concentrations decreased rapidly with distance from Basin F, and reached negligible and/or regional baseline levels at the RMA boundaries (see last two columns of Table 4.7-9). Levels during Phase 2, Phase 3, and Phase 4 decreased dramatically from the Phase 1 values.

The decrease in concentrations from Basin F potential sources with distance as well as the impacts of prevailing wind flow are illustrated in dispersion model results for various individual worst-case sampling events shown in this report. These data confirm monitoring results and can be used to estimate impacts beyond the monitoring network.

4.7.5 SEASONAL CONSIDERATIONS

Table 4.7-10 shows the seasonal distribution of average and 24-hour maximum concentrations of pesticides measured at the three CMP perimeter sites during the combined FY88, FY89, and FY90 monitoring periods. Average aldrin, endrin, and isodrin concentrations were highest during the fall season, especially at AQ3 on the northern perimeter of the Arsenal. The highest average concentrations of chlordane and dieldrin were measured in the summer, again at AQ3. PPDDE was detected only during the summer, with the highest level at AQ1. The highest average level of PPDDT was also measured in the summer at AQ1. In general, summer and fall concentrations were higher than those measured in winter and spring.

It appears from these results that metropolitan Denver was not a significant source of pesticides during the typical inversion and brown cloud periods that affected concentrations of TSP, metals, and VOC. Rather, a regional source of pesticides may be north of the Arsenal, because there were relatively high readings at AQ3 during FY90. It is also possible that the Basin F area may have contributed slightly to the impacts at AQ3.

4.7.6 SVOC NONTARGET ANALYTE RESULTS

A total of 36 SVOC polyurethane foam (PUF) samples were collected for FY90 under the CMP at Rocky Mountain Arsenal. The samples were analyzed by two laboratories, Environmental Science and Engineering in Denver (ESE/D) and MidWest Research Institute (MRI). Table 4.7-11 presents a listing of the nontarget SVOCs detected at the CMP monitoring sites. The table includes the number of detections for compound groupings such as alkanes, carboxylic acids, and unknowns. Chemical groupings were chosen from the laboratory's findings for discussion as they best represent the types of compounds detected rather than specific identifications. ESE/D and MRI identified all peaks that were greater than 10 percent of the internal standard area as nontargets and ranked them according to estimated concentration. ESE/D reported the top 10 detections, while MRI reported all nontarget detections greater than 10 percent of the internal standard area.

Table 4.7-10 Combined Seasonal Organochlorine Pesticide (OCP) Concentrations (in $\mu\text{g}/\text{m}^3$)

Fall		Aldrin	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE ¹	PPDDT ²
AVERAGE								
Fall	AQ1	0.00102	0.00028	0.00052	0.00038	0.00035	*	0.00036
	AQ3	0.00625	*	0.00137	0.00089	0.00061	*	*
	AQ5E	0.00136	0.00032	0.00060	0.00042	0.00036	*	0.00039
	AQ5F	0.00161	*	0.00063	0.00042	0.00034	*	*
Winter	AQ1	*	0.00025	0.00032	0.00030	*	*	0.00027
	AQ3	*	0.00025	0.00032	*	*	*	*
	AQ5E	*	0.00027	0.00029	*	*	*	*
	AQ5F	*	0.00026	0.00028	*	*	*	0.00030
Spring	AQ1	0.00028	0.00026	0.00038	*	*	*	*
	AQ3	*	0.00029	0.00086	*	*	*	0.00031
	AQ5E	*	0.00027	0.00039	*	*	*	*
	AQ5F	*	0.00030	0.00038	*	*	*	*
Summer	AQ1	0.00040	0.00040	0.00073	0.00043	0.00023	0.00046	0.00052
	AQ3	0.00104	0.00054	0.00160	0.00076	0.00026	*	0.00035
	AQ5E	0.00047	0.00036	0.00100	0.00063	0.00025	0.00031	0.00049
	AQ5F	0.00064	0.00032	0.00067	0.00038	*	*	*
24-HOUR MAXIMUM								
Fall	AQ1	0.00659	0.00037	0.00153	0.00087	0.00093	*	0.00083
	AQ3	0.02898	*	0.00607	0.00259	0.00242	*	*
	AQ5E	0.00945	0.00048	0.00278	0.00131	0.00078	*	0.00081
	AQ5F	0.00938	*	0.00268	0.00124	0.00065	*	*
Winter	AQ1	*	0.00033	0.00143	0.00112	*	*	0.00038
	AQ3	*	0.00034	0.00094	*	*	*	*
	AQ5E	*	0.00037	0.00058	*	*	*	*
	AQ5F	*	0.00033	0.00049	*	*	*	0.00057
Spring	AQ1	0.00036	0.00041	0.001423	*	*	*	*
	AQ3	*	0.00044	0.00360	*	*	*	0.00058
	AQ5E	*	0.00036	0.00084	*	*	*	*
	AQ5F	*	0.00035	0.00086	*	*	*	*
Summer	AQ1	0.00428	0.00149	0.00619	0.00264	0.00051	0.00576	0.00467
	AQ3	0.00673	0.00286	0.00559	0.00406	0.00072	*	0.00116
	AQ5E	0.00394	0.00120	0.00738	0.00459	0.00041	0.00231	0.00503
	AQ5F	0.00341	0.00097	0.00251	0.00122	*	*	*

* All values below CRL

1 PPDDE = Dichlorodiphenylethane

2 PPDDT = Dichlorodiphenyltrichloroethane

Table 4.7-11 Summary of SVOC Nontargets for FY90

Unknown ID	AQ1		AQ2		AQ3		AQSE	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Hydrocarbons								
(alkanes/alkenes)	0.0669	0.0167	0.0247	0.0177	0.0258	0.0668	0.0668	0.0668
Analytical Interference								
Analytical Surrogates	0.0301	0.0301	0.0177	0.0177				
Benzene, 2,4-diisocyanato-								
1-methyl-(9Cl)								
Carboxylic Acids								
Chlorinated Hydrocarbons								
Iron-Containing Hydrocarbons								
Ketones								
Nitrogen-Containing								
Hydrocarbons								
Organic Acids								
Oxygenated Compounds	0.0335	0.0201	0.0318	0.0318				
Phenols								
Phthalates	0.0335	0.0335	0.0353	0.0353				
Polynuclear Aromatics	0.0301	0.0167	0.0212	0.0212				
Unknowns								

Table 4.7-11 Summary of SVOC Nontargets for FY90 (continued)

Unknown ID	AQ5F		AQ6		# Hits	AQ8		AQ9	
	Max.	Min.	Max.	Min.		Max.	Min.	Max.	Min.
Hydrocarbons (alkanes/alkenes)	0.0732	0.0183			12				
Analytical Interference					0				
Analytical Surrogates			0.1062	0.1062	0				
Benzene, 2,4-diisocyanato- 1-methyl-(9Cl)			0.0319	0.0319	0	0.0375	0.0375		
Carboxylic Acids			0.0366	0.0366	1				
Chlorinated Hydrocarbons	0.0366	0.0366			0				
Iron-Containing Hydrocarbons					0				
Ketones	0.0220	0.0220			1				
Nitrogen-Containing Hydrocarbons					0				
Organic Acids					0			0.0763	0.0763
Oxygenated Compounds	0.0220	0.0220			1				
Phenols					0				
Phthalates	0.0220	0.0220			2	0.0375	0.0375		
Polynuclear Aromatics	0.0256	0.0256			1				
Unknowns			0.1062	0.0142	0	0.1875	0.0225	0.3817	0.0382
					5	8			6

Table 4.7-11 Summary of SVOC Nontargets for FY90 (continued)

Unknown ID	AQ23		AQ26		AQ35		AQ36	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
					# Hits	# Hits	# Hits	# Hits
Hydrocarbons (alkanes/alkenes)			0.0592	0.0178	6	0	0.0370	0.0259
Analytical Interference					0	0		0
Analytical Surrogates					0	0		0
Benzene, 2,4-diisocyanato- 1-methyl-(9CI)					0	0		0
Carboxylic Acids	0.0333	0.0300	0.0363	0.0309	2	0.0228	0.0388	0.0314
Chlorinated Hydrocarbons			0.0726	0.0292	3	0.0829	0.0175	0.0175
Iron-Containing Hydrocarbons					0	0		0
Ketones	0.0267	0.0267	0.0327	0.0180	3	0.0207		0
Nitrogen-Containing Hydrocarbons			0.0726	0.0360	2	0		0
Organic Acids					0	0		0
Oxygenated Compounds					0	0	0.1110	0.0222
Phenols			0.0216	0.0173	2	0.0249		0
Phthalates					0	0		0
Polynuclear Aromatics					0	0	0.0209	0.0209
Unknowns	0.1001	0.0133	0.2179	0.0125	62	0.0762	0.1163	0.0175
					14	16		20

The number of observed nontargets totaled 314 for the 36 environmental samples. Two thirds of the nontargets (202) were considered by the laboratories as having less than an 80 percent match with spectra found in the National Bureau of Standards Spectral Library, and were placed in the unknown category. There were 43 detections of simple alkanes that are more commonly known as hydrocarbons, which accounted for 40 percent of the compounds that could be identified. Carboxylic acid detections numbered 14 and comprised approximately 10 percent of the total nontargets that were classified.

Two groups are associated with common contaminants either as ubiquitous in the environment, phthalates, or as laboratory contaminants, extra analytical surrogates. Additionally, there is documentation that the analysis of the PUF displays breakdown products from the PUF itself. These observations have been made by Hunt et al. (1986). Compounds such as phenol, an organic acid, diisocyanates, amines, and an oxygenated hydrocarbon have been associated with this type of sampling media. These groups were detected as nontargets in the environmental samples.

The rest of the grouping detections totaled nine or less each and included the groups chlorinated hydrocarbons, iron-containing hydrocarbons, ketones, and polynuclear aromatic compounds. Each of these groups comprised less than 10 percent of the total nontargets that were identified.

A summary of the blank nontarget results (excluding laboratory method blanks) is listed in Table 4.7-12. Most of the detections (43) fell within the unknown group, while the others encompassed all the same PUF media interferences described above by Hunt et al. (1986). Results from the blank analyses indicate that certain nontargets observed in the environmental samples are directly related to the PUF sampling media and should not be considered as environmental nontargets.

Table 4.7-12 Summary of SVOC Nontargets Blank Data for FY90

Unknown ID	AQ3FB		AQ8FB		AQ10FB		FC2FB		M1FB	
	Max.	Min. # Hits	Max.	Min. # Hits	Max.	Min. # Hits	Max.	Min. # Hits	Max.	Min. # Hits
Hydrocarbons	10	5	3	0	0	0	0	0	0	0
(alkanes/alkenes)										
Analytical Interference	6	6	1	0	6	1	10	2	0	0
Analytical Surrogates			0	0	30	1	0	0	0	0
Benzene, 2,4-diisocyanato-										
1-methyl-(9CI)			0	0	0	0	0	0	0	0
Carboxylic Acids			0	0	0	0	0	0	0	0
Chlorinated Hydrocarbons			0	0	0	0	0	0	0	0
Iron-Containing Hydrocarbons			0	0	0	0	0	0	0	0
Ketones			0	0	0	0	0	0	0	0
Nitrogen-Containing										
Hydrocarbons			0	0	0	0	0	0	0	0
Organic Acids			0	30	6	1	0	0	0	0
Oxygenated Compounds			0	0	0	0	0	0	0	0
Phenols			0	7	0	0	0	0	0	0
Phthalates			0	0	0	0	0	0	0	0
Polynuclear Aromatics			0	0	0	0	0	0	0	0
Unknowns			0	30	7	5	100	4	20	5

UNCLASSIFIED

UNCLASSIFIED